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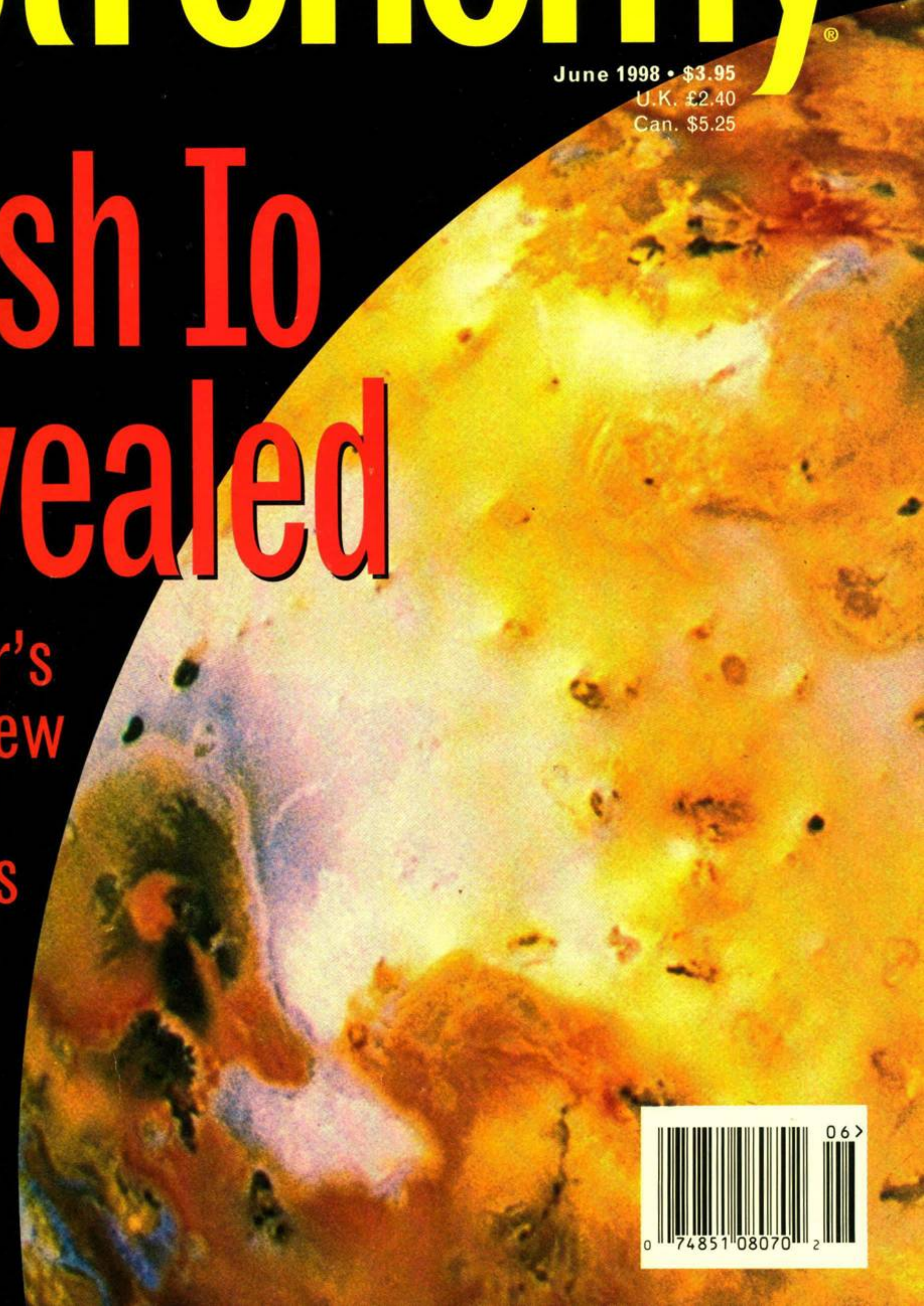


Fresh Io Revealed

In Jupiter's Realm: New Faces of its Moons

Our Guide to Great Eyepieces

LX50

Advanced technology at the most affordable prices *ever.*

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

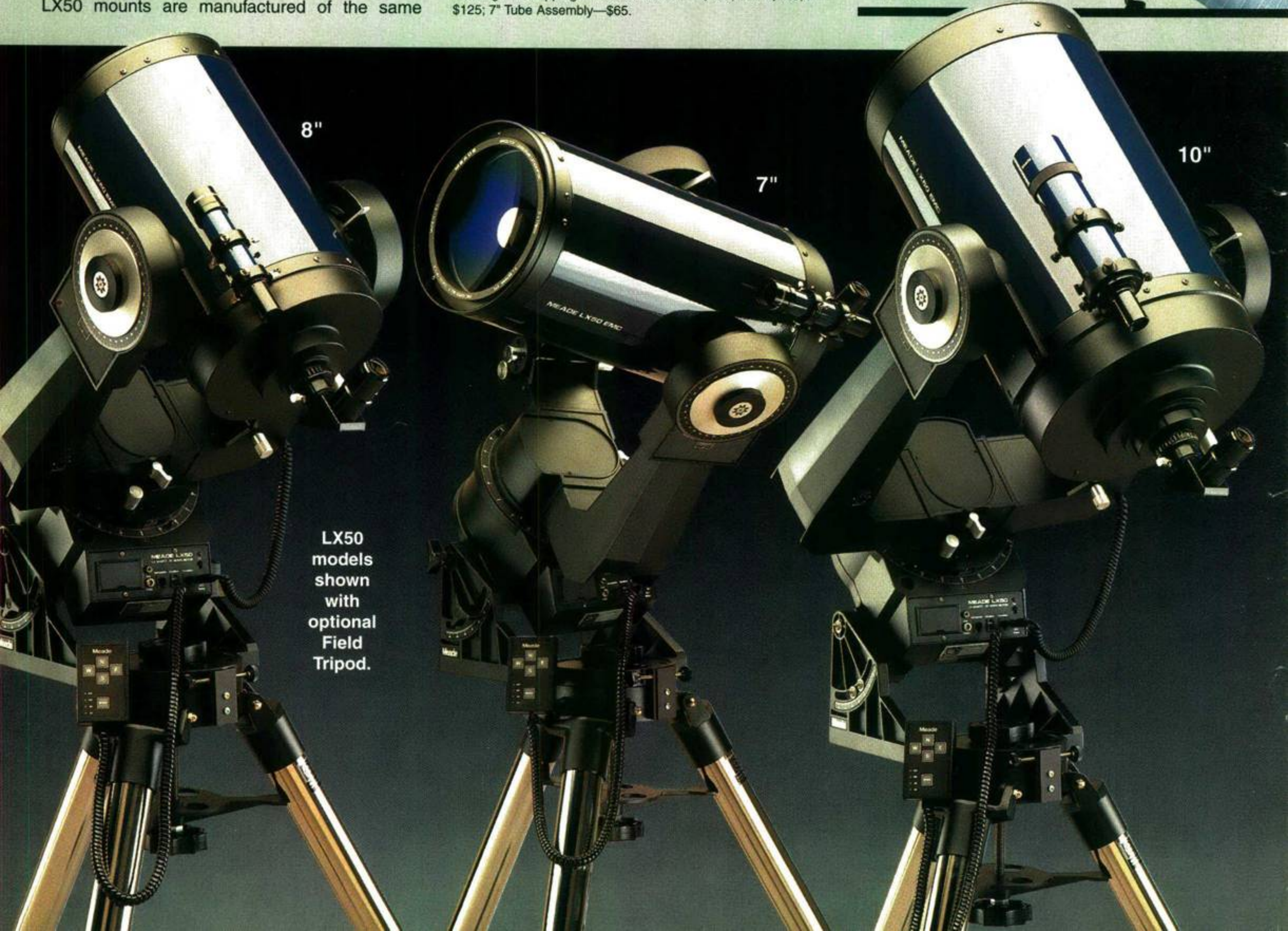
8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

only $495!

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



8"

7"

10"

LX50 models shown with optional Field Tripod.

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

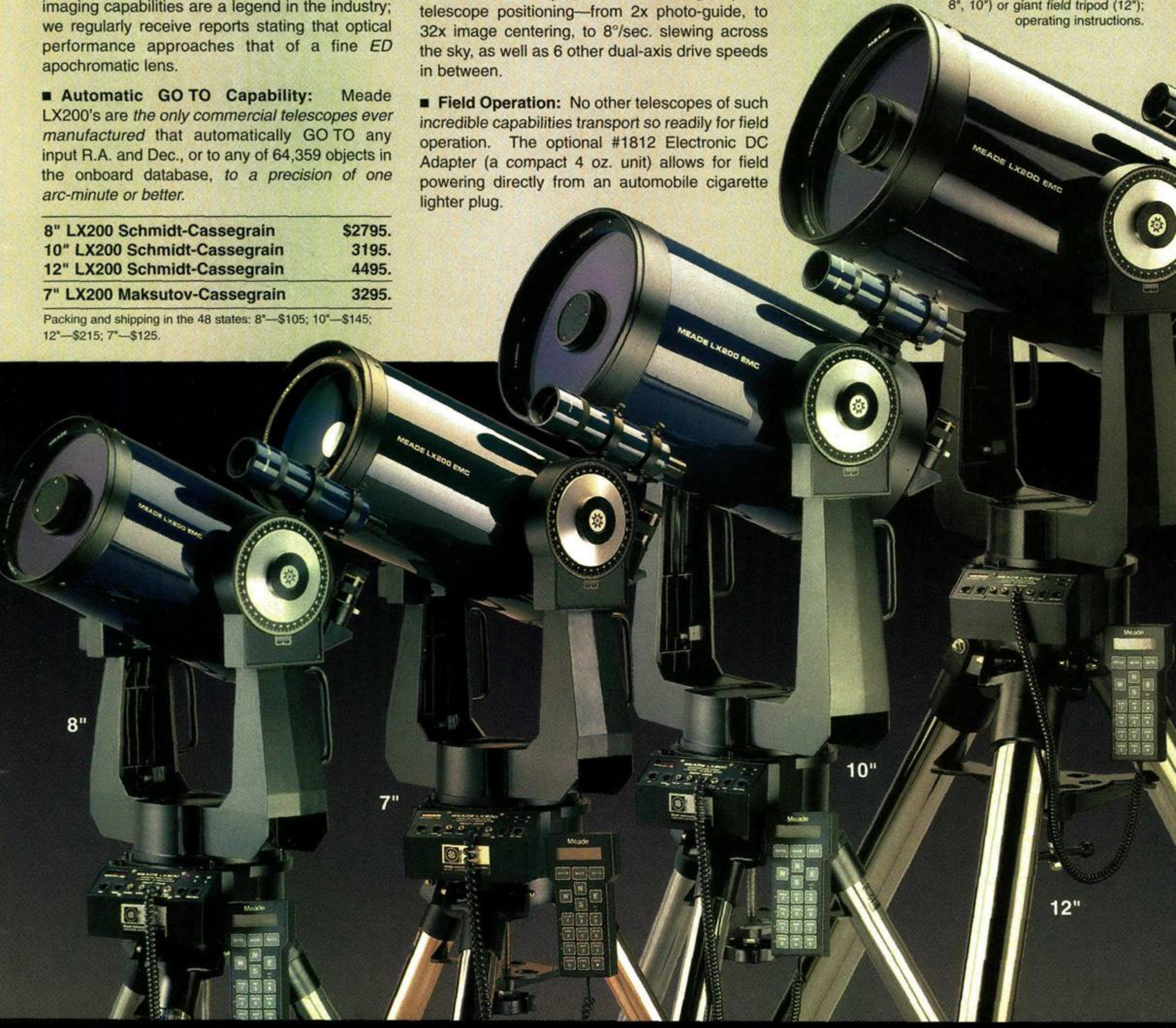
- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

- **Meade LX200 High-Precision Pointing™** is *so precise* it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such *incredible capabilities transport so readily for field operation.* The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; *heavy-duty fork mount* with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; *8 x 50mm viewfinder;* 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.



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COVER PHOTO: NASA/JPL

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From *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

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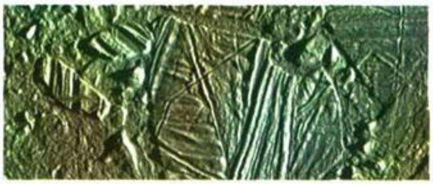
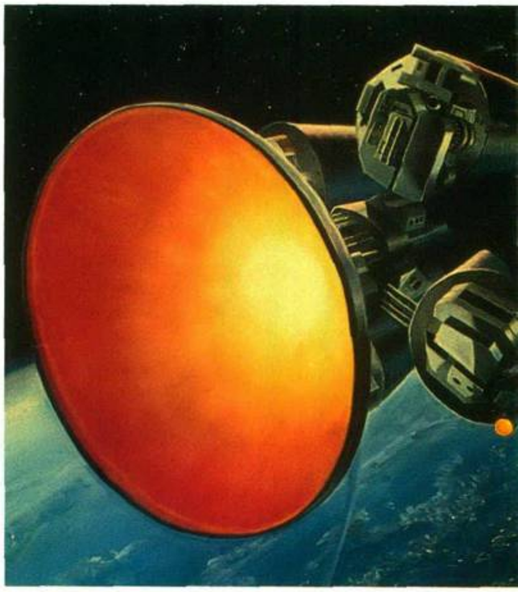
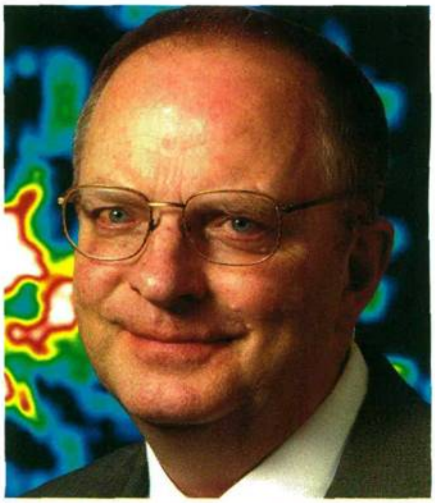
NASA/JPL







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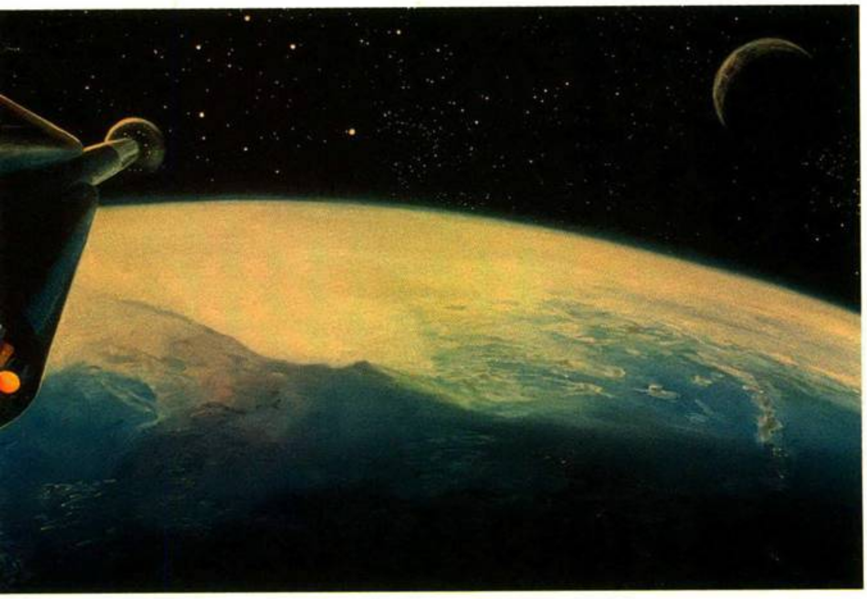

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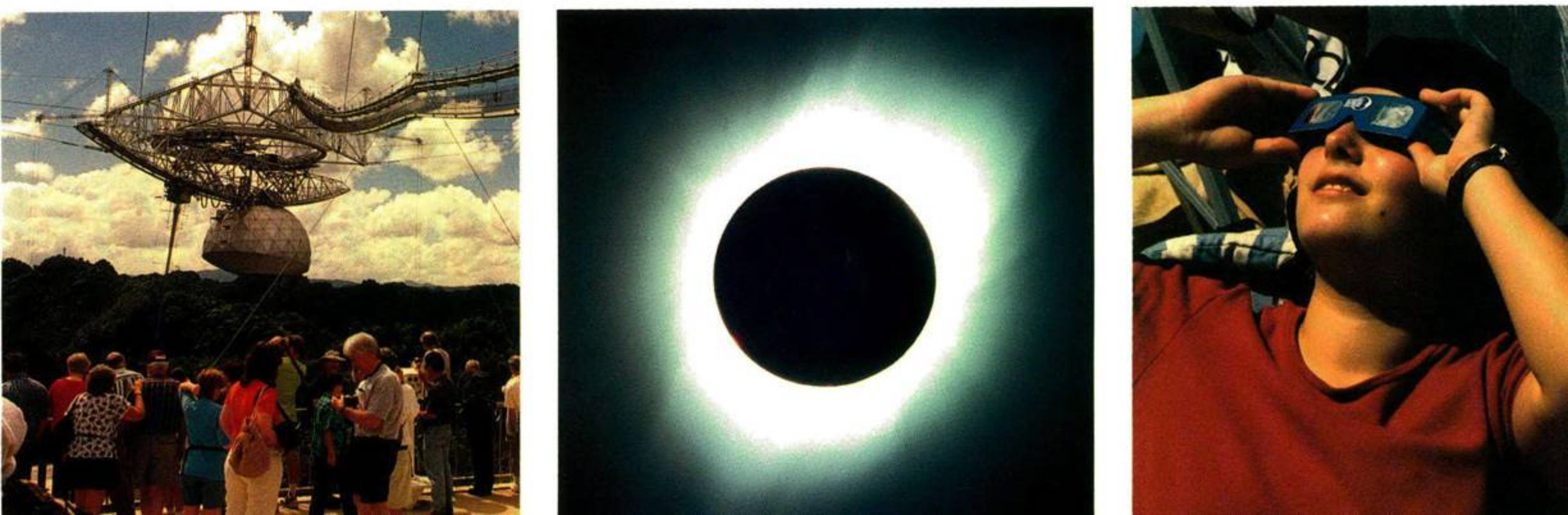

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Chasing Shadows

It lasted only three and a half minutes, this February eclipse, yet thousands of people were willing to build their winter vacations around it. On our own cruise we hosted honeymooners, very extended families, travelers laden with telescopes and cameras, and others with only the solar specs we provided. We had people from 17 countries and almost every state in the union. One group of six Taiwanese joined us; only two of them spoke English. Students from a Colorado middle school science class sold T-shirts and washed cars to raise the money to take this trip. A few cruisers had chased eclipses before; some had failed to see one because of bad weather. For one guy, this was the fourth effort. So when rain began to fall an hour before the eclipse, he grew understandably tense. Good luck for us all, our ship's captain steered into clear skies with several minutes to spare. For many of us, such as five-year-old Christopher Eicher at left, this was the first eclipse — and the first try.

Clockwise from top left: Jeanette Brown, Peter Sutter (Bonnie's husband), Lynda and Dave Eicher, Evelyn and Rich Talcott, Patti Kurtz, Chris Eicher, Bonnie Gordon

Dave Eicher

Lynda and Chris Eicher

Five *Astronomy* editors made the trip, hosting 430 guests with help from staff members of Specialty Tours. We did a lot of talking formally and informally. Rich Talcott was particularly popular because he wrote a book about eclipses called *Chasing the Shadow*. But all of us were busy enough sharing what we knew. And we (and our families) cleaned up pretty nicely for the parties, as you can see above. For the full story and great images, go to pages 52 and 121.

Evelyn Talcott

Rich Talcott with TV crew in San Juan

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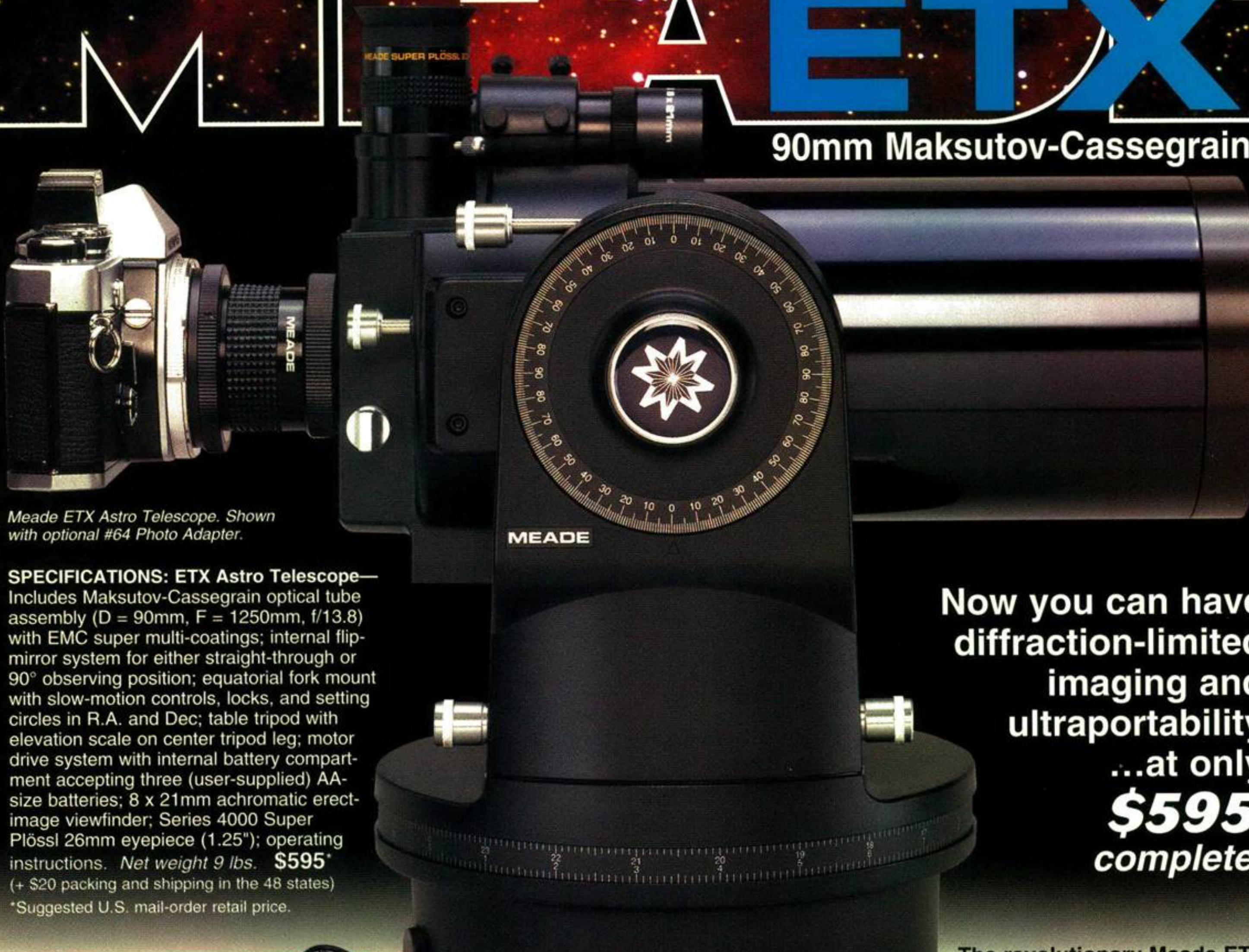
MEADE ETX

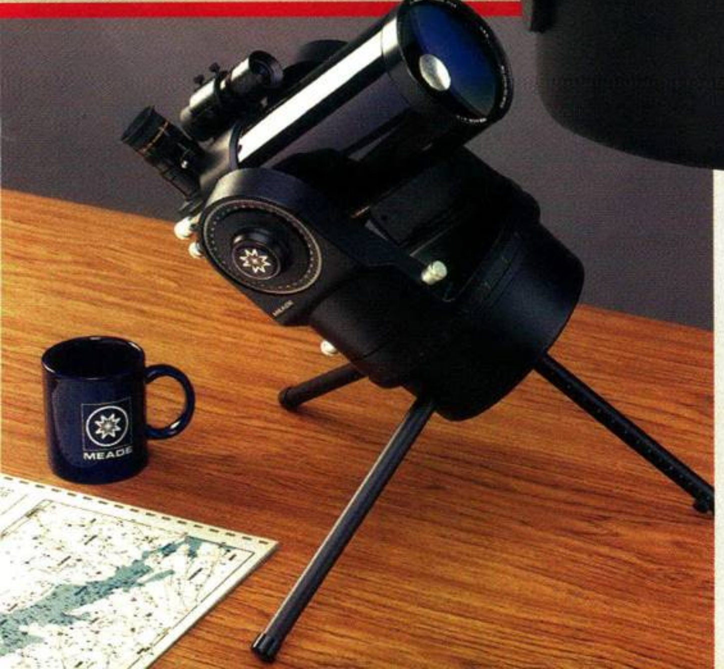
90mm Maksutov-Cassegrain



Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$595***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$595*, *complete!*



The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds*, just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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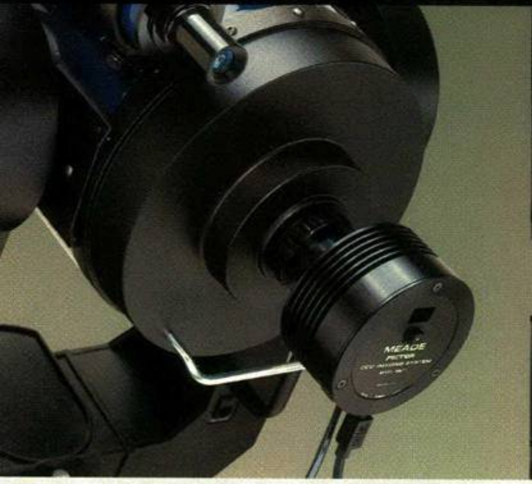
Meade Pictor 208XT
AUTOGUIDER/IMAGER

complete **$495**



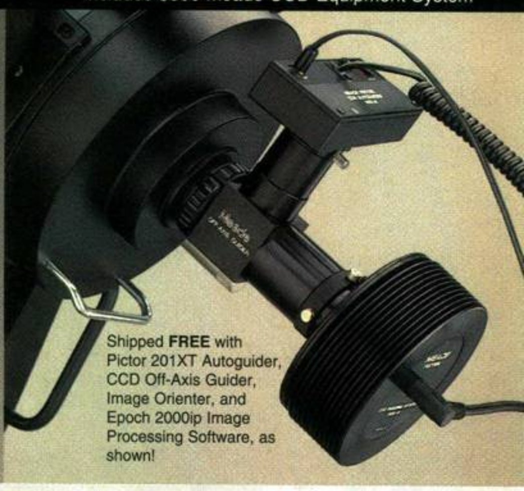
Meade Pictor 216XT
AUTOGUIDER/IMAGER

complete **$695**

Meade Pictor 416XT
AUTOGUIDER/IMAGER

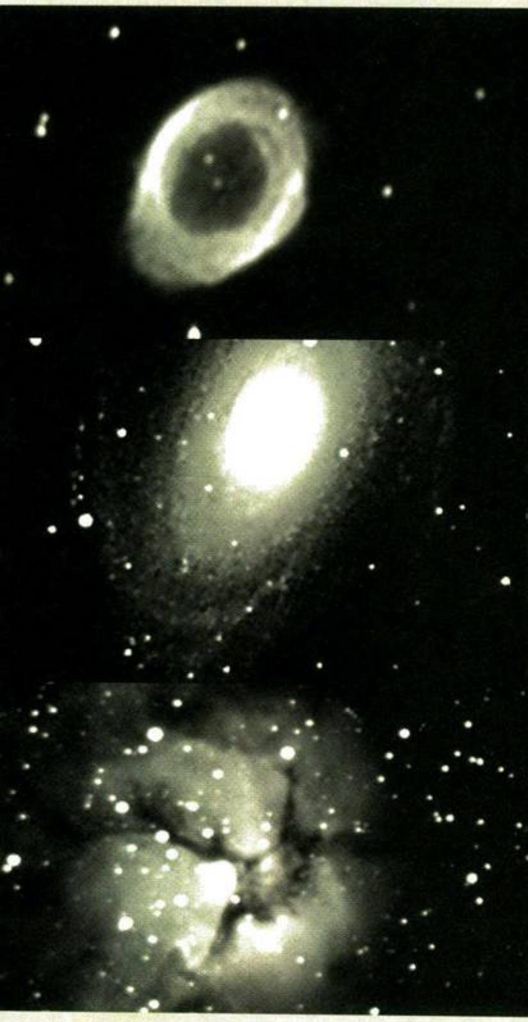
complete **$1695**

includes $800 Meade CCD Equipment System

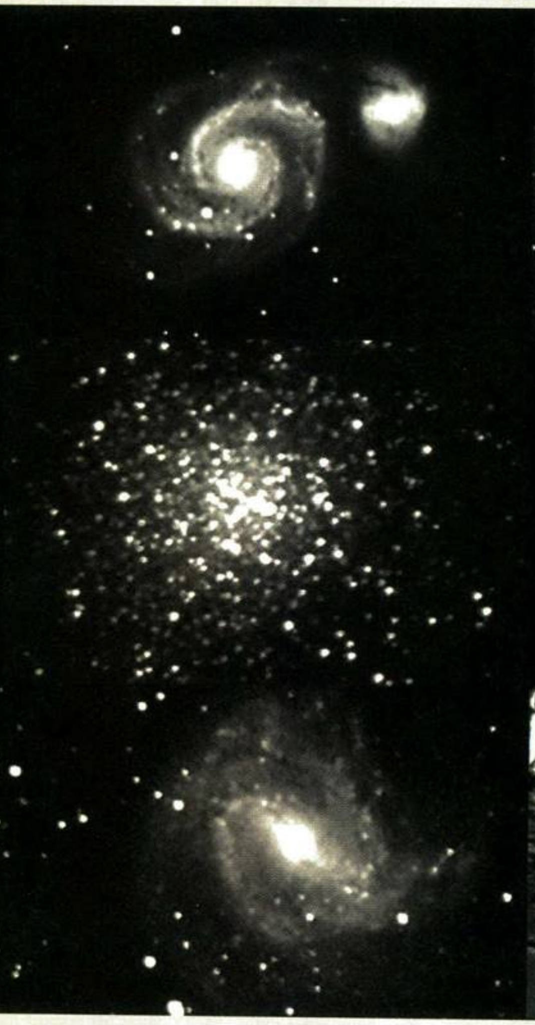


Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

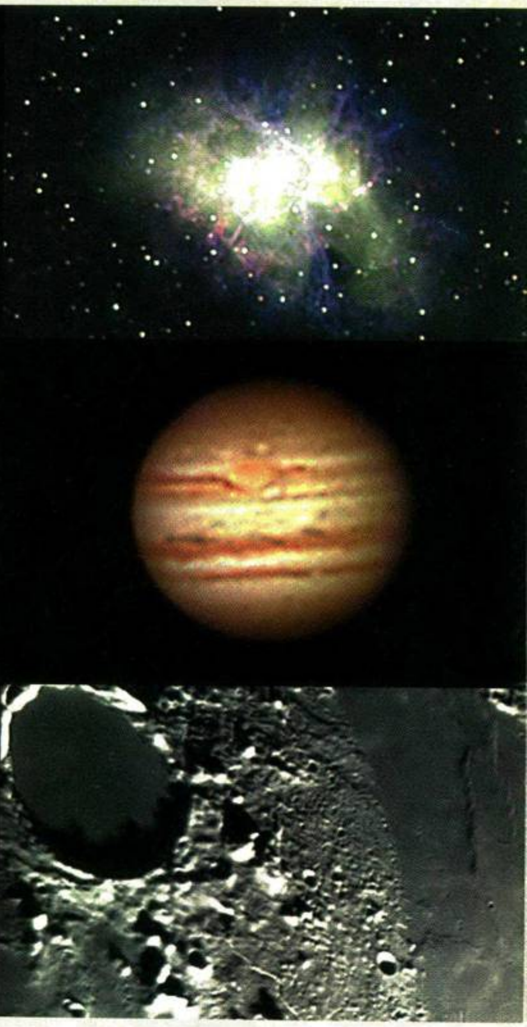
Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 94-page Meade 1997 General Catalog.***



Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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Model 102ACHR/500:
4" f/9 Achromatic
Refractor — **$995.**

Model 102APO/500:
4" f/9 *ED* Apochromatic
Refractor — **$1695.**

Model 114NT/500:
4.5" f/8 Newtonian
Reflector —
$595.

Model 127NT/500:
5" f/8 Newtonian
Reflector — **$695.**

Model 203SC/500:
8" f/10 Schmidt-
Cassegrain
— **$1295.**

MEADE 500-Series

Experience all of the high-resolution optical performance and mechanical precision of a MEADE reflector, refractor, or Schmidt-Cassegrain, at a moderate pricing level. Each complete 500-Series model includes the all-new MEADE LXD 500 equatorial mount with dual-axis worm gears, engraved setting circles, micrometric slow-motion controls in RA and Dec, rigid aluminum tripod, and a full complement of accessories. Choose from among five models the one that's right for your budget and observing requirements. *For complete details send for your free copy of Meade Bulletin 500.* Optional systems for Meade 500-Series telescopes include:

#1701 Single-Axis RA Drive System	**$145.**
#1702 Dual-Axis Drive System, with 4-speed hand controller	**195.**
#812 Polar Alignment Finder	**49.**

Shown with optional #1702 Dual-Axis Drive System

Prices shown are suggested U.S. national mail-order retail prices.
Packing and shipping: 4" models—$55; 4.5" and 5"—$45; 8"—$65.

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

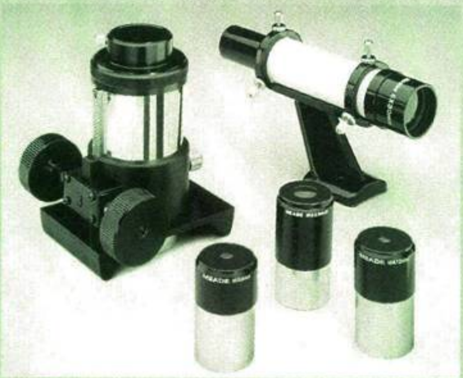
5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right)*, tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only $49.95!



Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

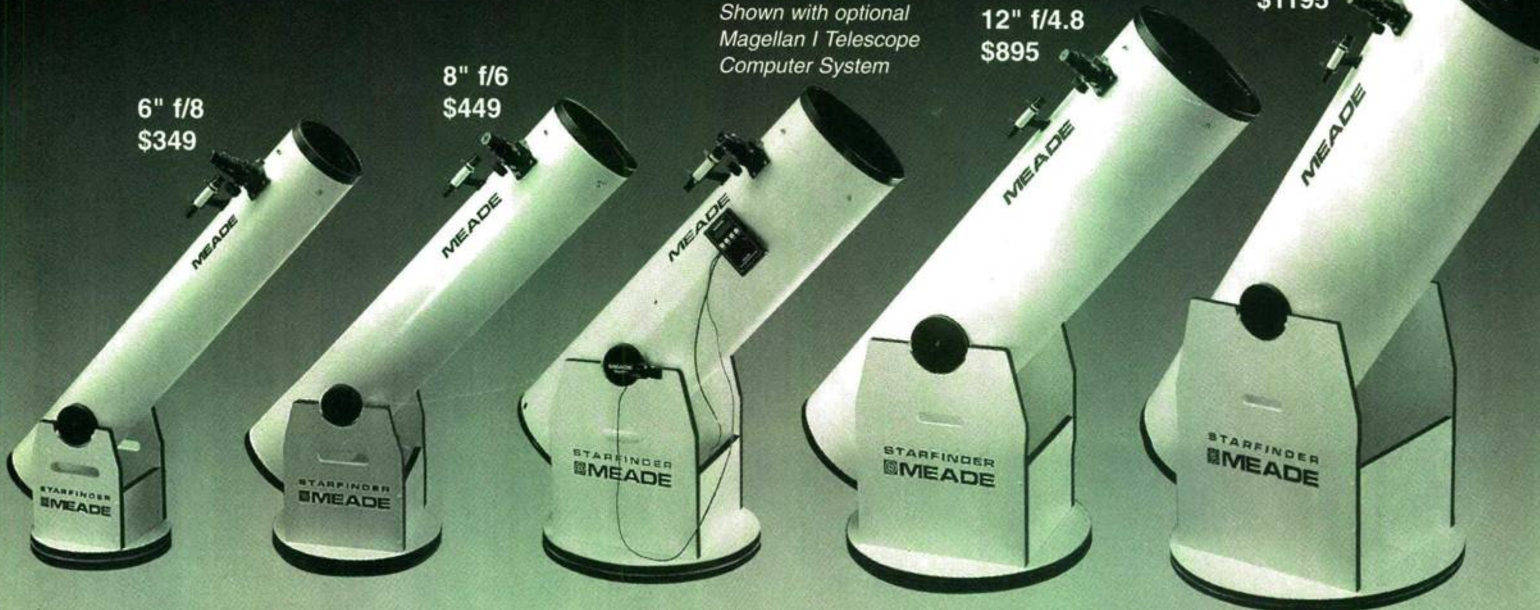
MEADE
ENTER
MODE
PREV
NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***

All prices plus packing and shipping, as noted above.



6" f/8 $349

8" f/6 $449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

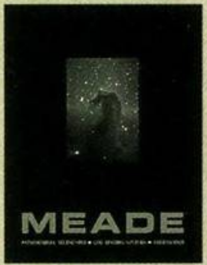
12" f/4.8 $895

16" f/4.5 $1195

MEADE

STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*



The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 100-page Meade General Catalog.

Write, call, or fax Meade Instruments for your free copy!

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-*dia.* pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION

Meade Instruments Corporation

World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

6001 Oak Canyon, Irvine, California 92620 ☐ (714) 451-1450
FAX: (714) 451-1460 ☐ *www.meade.com*

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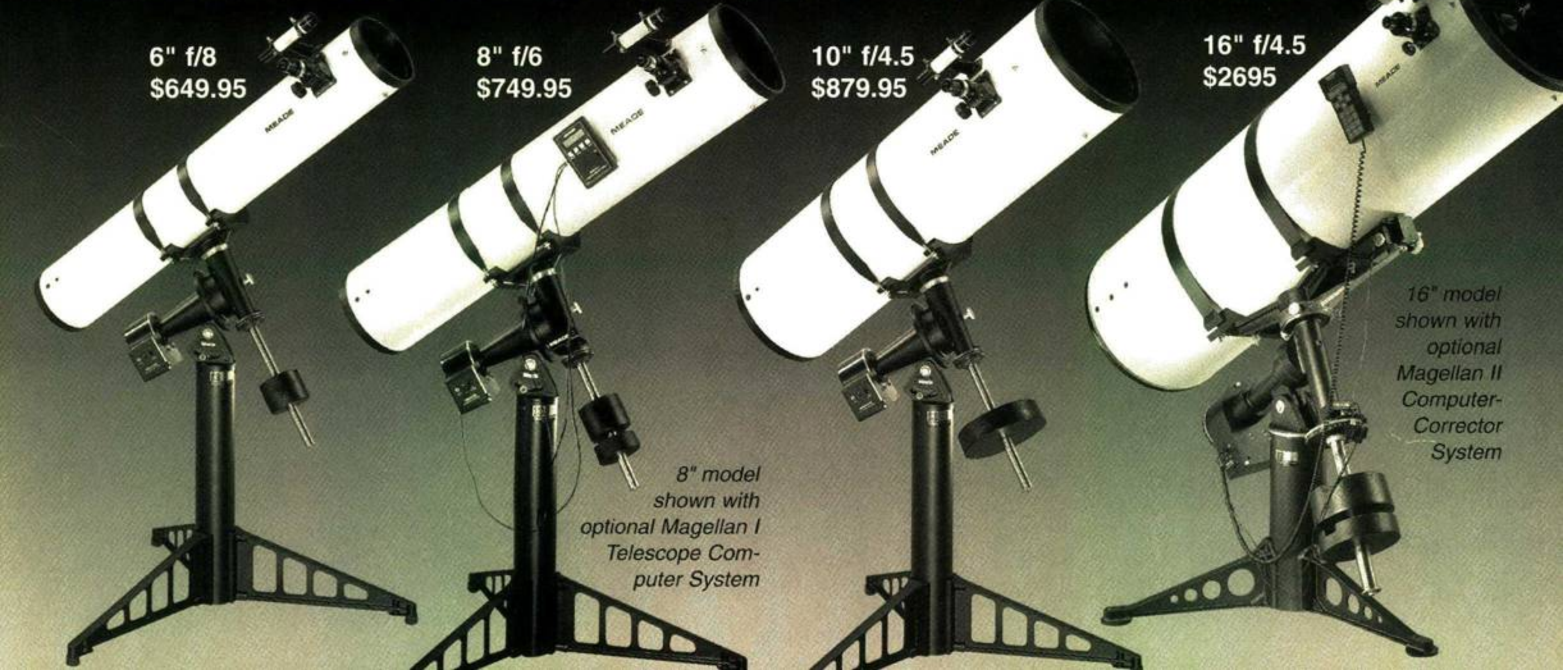
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



6" f/8
$649.95

8" f/6
$749.95

10" f/4.5
$879.95

16" f/4.5
$2695

8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

8" LX10

8" LX10 DELUXE

The optical performance of a Meade 8" LX200 Schmidt-Cassegrain...for only *$995!*

8" LX10: For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. **Equatorial Fork Mounting:** The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. **Cordless, DC-Powered Electronic Motor Drive:** With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours. **Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging. **Hand Controller:** Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

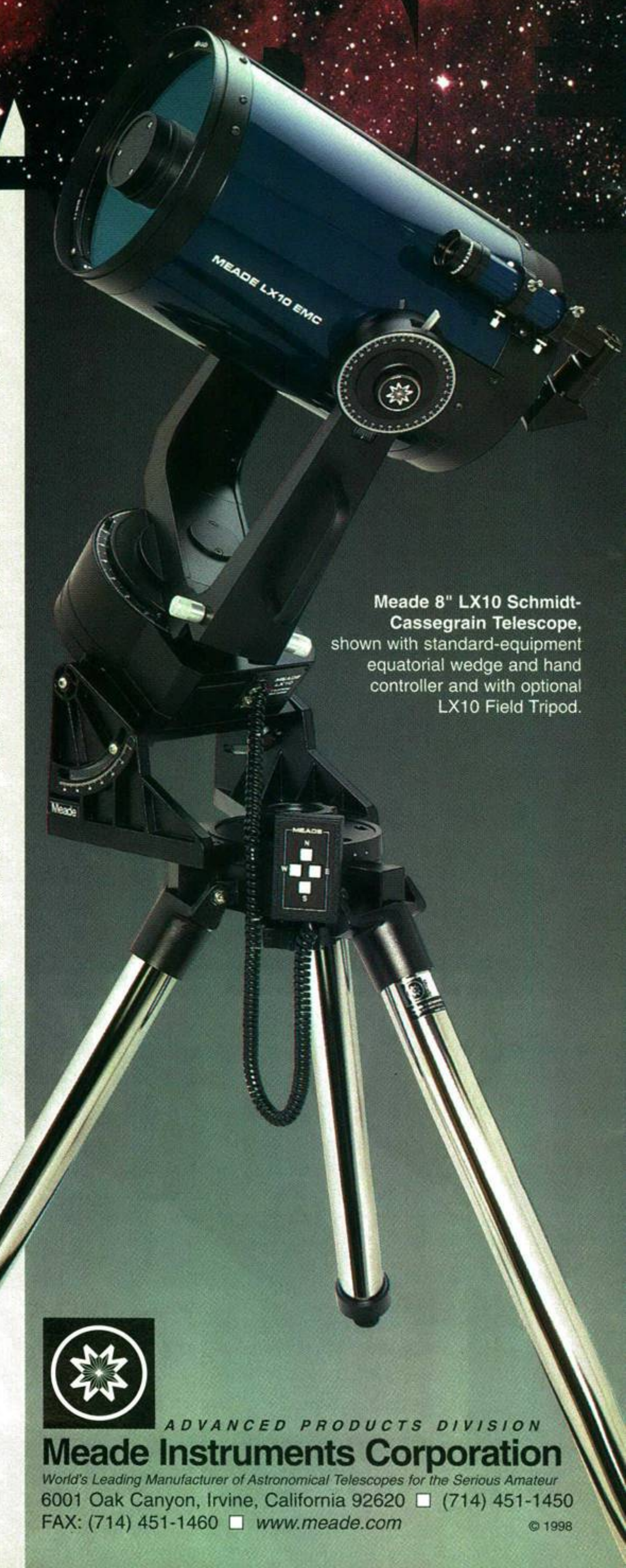
SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions. **$995.** (+ $65 packing & shipping in the 48 states)

8" LX10 Deluxe: At only $1149 the 8" LX10 Deluxe includes (a) the large-aperture Meade #544 8 x 50mm viewfinder (in place of the standard 6 x 30mm finder); (b) a premium-grade Meade Series 4000 Super Plössl 26mm eyepiece (in place of the standard MA25mm eyepiece); and (c) the LX10 Electric Declination Motor System, permitting dual-axis guiding corrections at 2x speed—all at substantially lower cost than if the respective accessories were purchased separately.

SPECIFICATIONS: 8" Model LX10 Deluxe — Identical in all specifications to 8" Model LX10, above, but with Electric Declination Motor System provided as standard equipment, permitting dual-axis corrections at 2x speed; and with Meade #544 8 x 50mm achromatic viewfinder and Series 4000 Super Plössl 26mm multi-coated eyepiece included in place of the 6 x 30mm viewfinder and MA25mm eyepiece of the LX10. **$1149.** (+ $65 packing & shipping in the 48 states)

Field Tripod for LX10 or LX10 Deluxe	**195.**
Electric Declination Motor System for LX10	**95.**
#2014 Magellan I Telescope Computer System for LX10 or LX10 Deluxe, with 12,218-object database	**375.**

The 100-page Meade General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers.
Prices shown are suggested U.S. mail-order prices.



Meade 8" LX10 Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

ADVANCED PRODUCTS DIVISION

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FAX: (714) 451-1460 ☐ *www.meade.com*

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MEADE
EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930**, each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

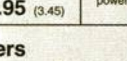
each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

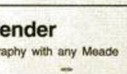
Camera Adapters



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (2.98)

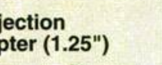
Variable Tele-Extender



For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters; each eyepiece includes a fold-down rubber eyeguard for comfortable observing. Made exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters; rubber eyeguard. Apparent field: 44°.

$79.95 (3.79)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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Martian Music

My interest in astronomy goes back to the days in the 1950s when I dreamed of a return of Halley's Comet. Growing up, I never missed a chance to talk to folks who witnessed the comet in 1910. In my residency training at Charity Hospital in New Orleans, I even made time to ask elderly patients about it.

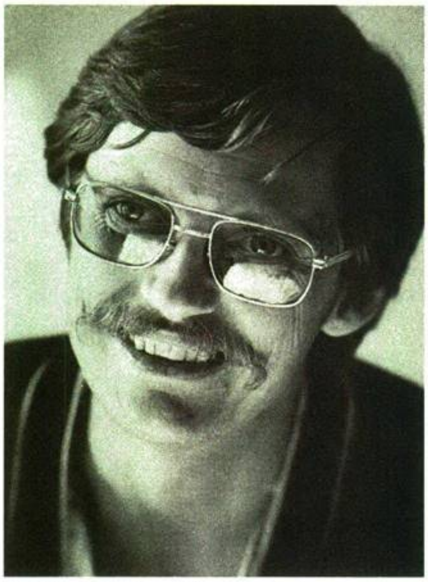
I always had a vision of walking out onto the driveway with a couple of children and pointing out the return in 1986. It seemed a cruel irony that my fantasy came so close to being true. Though I had two children by then and they were each old enough to point out Comet Halley, one of them was blind. This fact has underscored how beautiful the universe is to me, more so than any fantasies I may have had growing up — which brings me to Mars.

With Yogi and Casper becoming household names, with photos of martian sunsets and wispy clouds adorning your pages, I'm moved to wonder why NASA has never thought to make a simple audio recording from the surface of Mars. I would think that since we're so interested in its atmosphere we might also want to know what that atmosphere sounds like. Computers on board would make it simple. Why not take an inexpensive microphone, sound card, and software to capture sound in a frugal .WAV file and broadcast it to us along with the pictures? In fact, a stereo, high-fidelity file would take up only about ten megabytes per minute of sound — cheap by photo standards.

I may never be able to show my son what Mars looks like — I can't even show him what Earth looks like — but it would be a thrill for him (and many like me) to hear what it sounds like. — *Gerard M. DiLeo, Mandeville, Louisiana*

How It All Began

I recently received the January 1998 issue of *Astronomy* and made note of the 25-year anniversary. It made me remember way back to the late 1950s and early 1960s when I was a young man with big hopes. I was planning to go into astronomy as a career and was doing everything I could to make progress in that direction. In those days, I was living in the tiny town of Plover in central Wisconsin, near Stevens Point. In the end, I didn't become an astronomer, but it is still one of my passions and always will be.


Astronomy

Stephen Walther, *Astronomy's* founder

When I think back 35+ years, one of the things I remember most is another young man with a passion for astronomy. As I recall, he was about 16 or so when we met. He was full of questions and enthusiasm and sometimes seemed to be almost a pest with his need to know a million things about everything. I met him through a mutual friend, Clarence. I had a 10-inch Newtonian at the time, and Clarence also had a scope. We spent many nights observing from Clarence's backyard, and the other young man would frequently join us to roam the heavens and work with us in our attempts at astrophotography. We all had fun learning new things and enjoying the sky.

After a few years, life, as always, moved on in new directions. I gravitated away from astronomy and a few years later, Clarence died. I lost contact with the young man. Except for an occasional article in *Sky & Telescope,* I didn't hear any more about him until I learned, several years later, that he, Stephen A. Walther, had founded *Astronomy* magazine. Somehow I had known that he would make some kind of mark on his world. All that inquisitiveness and enthusiasm just had to accomplish something exciting. I smiled, remembering back to nights in Wisconsin under the stars with questions flying a mile a minute. Some I could answer, others I couldn't — who knows where it will lead when a kid asks questions. So be patient next time; you never know what he or she may have to teach you.

I was saddened to hear a few years later of Walther's untimely death, but as I look at each issue of *Astronomy,* I know that his legacy lives on. I was also disappointed to see that you have removed the recognition of him as your founder from the contents page, but those of us who knew him remember. — *Dick Phelps, Plano, Texas*

Hungry for More Info

My compliments on the March issue's article "The Call of Mt. Pinos" — and a suggestion for future, similar articles. Several years ago I made the trip from Los Angeles to Mt. Pinos with my new 8-inch SCT. It was my first scope and the first opportunity I'd had to observe outside my severely light-polluted backyard in an L.A. suburb. Suddenly, any familiarity I may have had with the sky (all gained with a limiting magnitude of about 4) was gone. The Milky Way was a rich swarm of stars, clusters, and nebulae. The once-familiar constellations Delphinus and Sagitta took more than an hour to locate. Reading the article took me back to my own experiences at Mt. Pinos and I grin as I recall the sound of dozens of nearby servo motors — like a robot convention in the dark.

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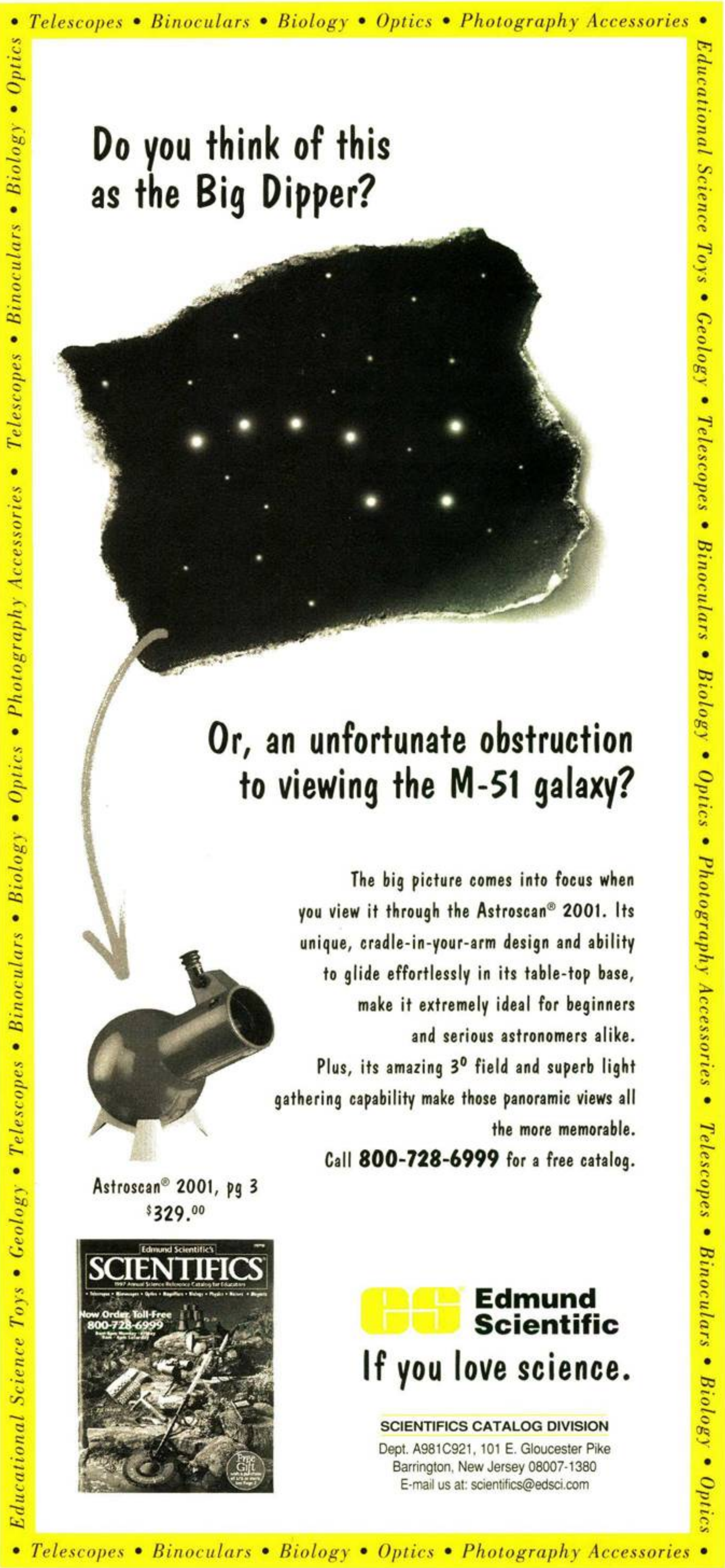

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I hope you'll decide to run similar articles focusing on the country's favorite dark-sky sites in the future. I also hope that when you do, you will include some text describing the amazing equipment pictured. I've found myself staring dumbfounded again and again at some of the systems: those of Michael Stecker, Marty Germano, Tony and Daphne Hallas, and Kim Zussman. It would be fascinating to read the details of their equipment. What mount? What scope? Is that a home-made pier? Look at that guide scope on the Hallas's system. How are those monsters transported? How are they financed? Second mortgage? Visa?

Those of us with hopes to one day become power users like those pictured could benefit greatly from detailed descriptions of the systems and from profiles of their users. Thanks for the best article you've run in some time. — *Daniel Lynch, Grass Valley, California*

What Does a Crescent Venus Prove?

In the January 1998 issue Gerald D. Ruth states that a crescent Venus can be considered evidence that Copernicus was right. I'll agree that it is proof that Ptolemy was wrong, but it doesn't necessarily mean that Earth is moving. In the 16th century, Danish astronomer Tycho Brahe suggested an Earth-centered system in which the moon and sun orbit Earth, but the other planets orbit the sun. In the tychonic system the superior planets had to move also around Earth in their way around the sun. (For graphics and explanation, check out http://www.geocities.com/capecanaveral/hangar/3998/tychonic.html.) This model is geometrically equivalent to the Copernican one but leaves Earth static in the center. True evidence that Earth is moving was not found until 1838 when Bessel observed parallactic shift in the star 61 Cygni. — *Marc Vallbe, Barcelona, Spain*

Astronomy invites you to talk back. Send letters to Astronomy Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space or clarity.

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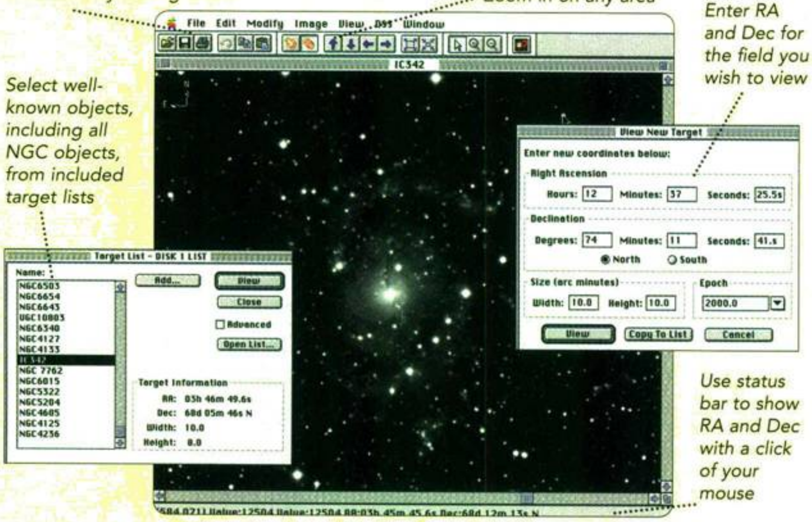
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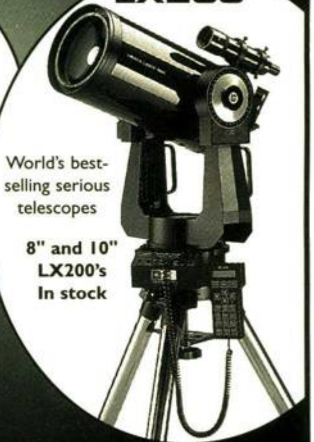

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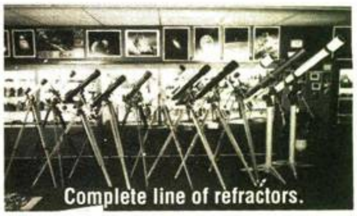

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LUNAR PROSPECTOR

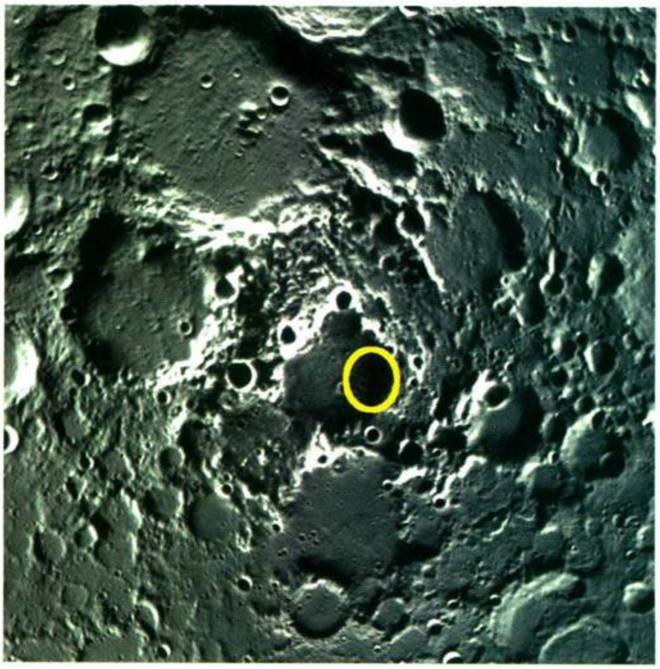
Water Ice Found at Moon's Poles

Precious resource lurks in cold traps

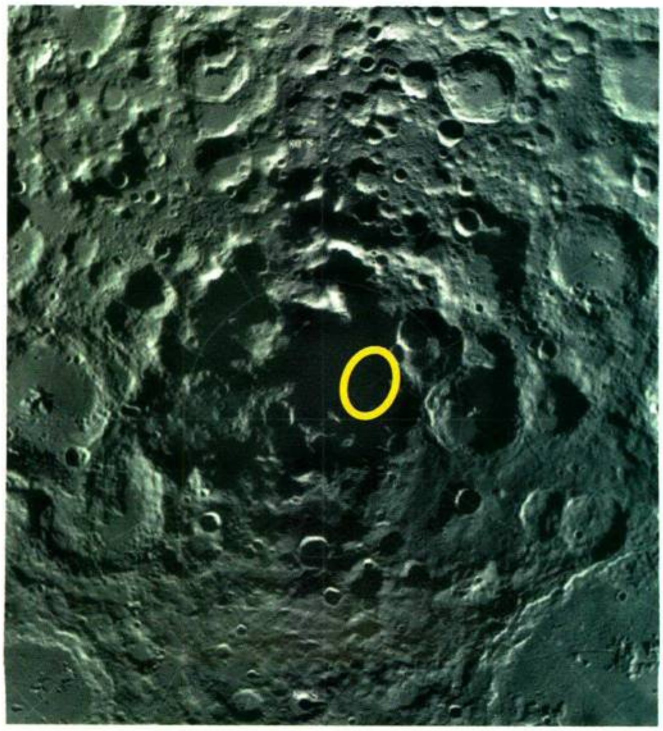
▶ NASA's $63-million Lunar Prospector mission has struck it rich. It has found a substance on the moon infinitely more valuable to future colonists than gold: water ice. Data from the spacecraft's neutron spectrometer show "the signature one would expect to find if water ice is present," says the mission's principal investigator, Alan Binder of the Lunar Research Institute.

The spectrometer detects neutrons liberated from the lunar soil as it's bombarded by cosmic rays and the solar wind. By gauging the energy of the neutrons, scientists can determine what atoms the neutrons hit. The spectrometer recorded a dip of medium-energy neutrons from both polar regions, a definitive signature of hydrogen, the primary component of water. Lunar Prospector found twice as much ice at the north pole as at the south pole.

The moon's ice exists in the form of small crystals mixed in with the rocky soil (or regolith) in a 0.3 to one percent ratio. Based on what Prospector has found so far, scientists estimate that the moon holds 11 million to 330 million tons (10 to 300 million metric tons) of water ice — enough water to fill a small lake. But even this wide estimate range could be off by a factor of 10 either way. Scientists don't completely understand the behavior of neutrons on the lunar surface, and the neutron spectrometer could only detect hydrogen to a depth of 1.5 feet (0.5 meter), when ice could be as deep as six feet (two meters). But 33 million tons of water ice — a conservative estimate — could support a community of 2,000 people for 100 years without water recycling.



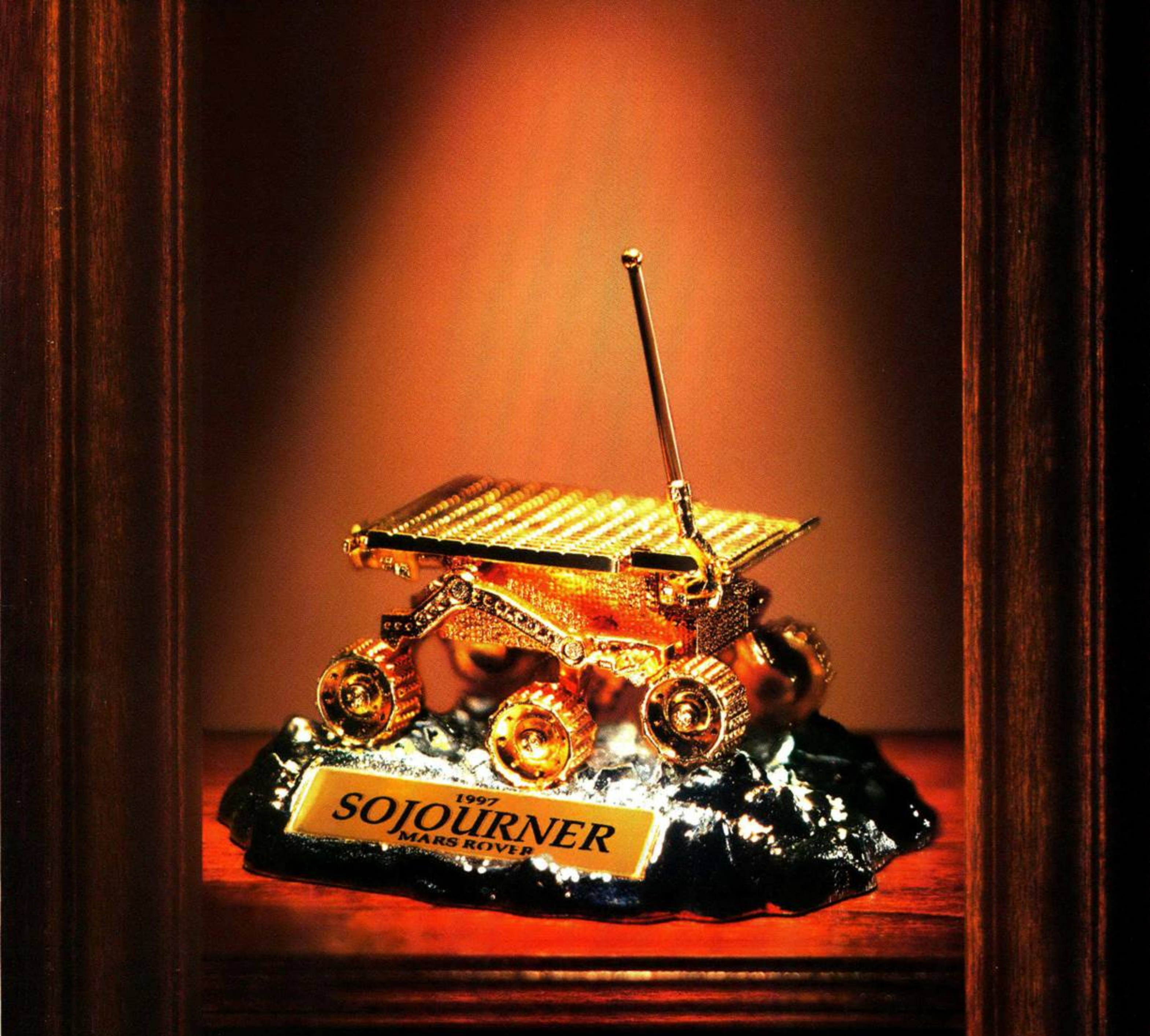
Lunar Prospector has found water ice over a 3,600 to 18,000 square-mile region (circled) of the north pole (above) and an 1,800 to 7,200 square-mile area of the south pole (below). U.S. Department of Defense



The water ice was presumably delivered when comets and meteors hit the moon. Ice can survive in permanently shaded craters in the polar regions, known as cold traps, the only places on the lunar surface never exposed to direct sunlight.

Radar studies conducted by the U.S. Department of Defense's Clementine spacecraft in April 1994 provided the first hint that water ice exists on the moon. But Clementine found water only at the south pole, and many scientists remained skeptical. Later radar experiments from the Arecibo radio telescope cast further doubt on the Clementine results. Lunar Prospector's spectrometers, however, are far more sensitive than the radar experiments and were specifically designed to detect water ice to a sensitivity of 0.1 percent.

Lunar Prospector, launched on January 6, 1998, currently orbits 62 miles (100 km) above the surface. As more data come in from its gamma-ray spectrometer, scientists will get much more precise estimates of the moon's volume of water ice. In January 1999, the spacecraft will dip down to a mere six miles, enabling its neutron and gamma-ray spectrometers to pinpoint the location of lunar ice.



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LIFE AND THE GALAXY

Danger Zone: Spiral Arms

Biting the bullet has become a habit for life on Earth if the work of two American researchers is correct. They have found evidence that mass extinctions — such as the death of the dinosaurs 65 million years ago — coincide with passages of the sun through one of the galaxy's spiral arms every 200 million years or so.

Spiral arms are giant shock waves that sweep around the Milky Way, compressing material into bright bands of new stars. The sun periodically enters a spiral arm as it orbits around the galaxy. Because spiral arms are denser than the rest of the galaxy, the solar system is more likely to encounter giant clouds of gas and dust when passing through them. These clouds weigh up to a million times the mass of the sun, so their gravity sends billions of comets from the outer solar system hurtling inward toward Earth.

In 1979, Victor Clube and Bill Napier of the Royal Observatory in Edinburgh, Scotland, suggested that passage through a spiral arm would expose Earth to asteroid-size objects in the arm itself, increasing the risk of giant impacts. In the December 1997 *New Astronomy*, Erik Leitch and Gautam Vasisht of the California Institute of Technology take this argument a step further, reporting the first evidence linking spiral-arm passages with mass extinctions.

Plotting the pattern of our galaxy's spiral structure, they estimated when the sun passed through the arms. They found that the dates of the six mass

(See "Danger Zone," p. 24)

Life-bearing planets in the galaxy M74, shown below, would do best to avoid the spiral arms.

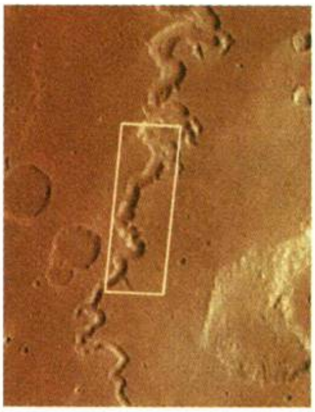
Hale Observatories

MARS GLOBAL SURVEYOR

A Dry Riverbed on Mars?

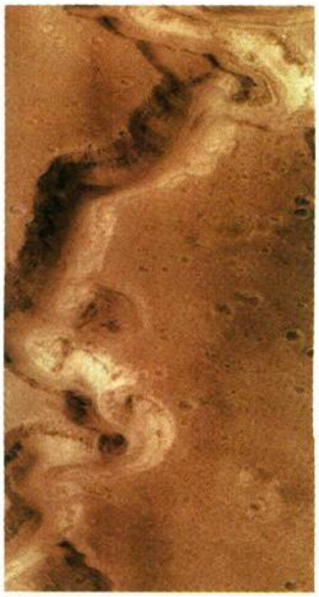
As Mars Global Surveyor continues to settle toward a mapping orbit, new discoveries are emerging.

The altimeter has gathered beautiful data with a height accuracy of better than a meter. One interesting result concerns the Tharsis dome, home of Mars's largest volcanoes. The whole structure of the Arsia Mons volcano, on the flank of Tharsis, appears tipped. This suggests that the dome was built not just by a long-term piling up of lava, as some researchers had thought, but by uplift, which tipped volcanoes such as Arsia Mons after they had formed.



This Viking mosaic of Nanedi Vallis shows the Mars Global Surveyor field in a box. NASA/JPL

The camera team has released a spectacular image of the channel system Nanedi Vallis. One of the great questions of Mars research is whether the river channels were active only during an early period when Mars had a thicker, warmer atmosphere, or whether Mars's climate has continually oscillated between wet and dry. In other words, did the channels flow only once, or in repeated episodes?



NASA/Malin Space Science Systems

Features the size of a small house appear in this high-resolution Mars Global Surveyor image of Nanedi Vallis. Notice the narrow channel at the upper right. It formed after the 1.6-mile-wide main channel, suggesting Mars had several episodes when liquid water could flow across the surface.

Nanedi Vallis provides some clues. As shown in the low-resolution Viking frame, it meanders across a plain and has "oxbow" features. These features are typical of a river system that has flowed for a long time and established an equilibrium with its floodplain, rather than a system formed in one catastrophic outburst. The new Surveyor image supports this by showing an exposed layer of harder material in the wall. If this is rock, it would suggest that the river was cutting through the rock for perhaps hundreds of millennia, because erosion through rock generally requires long time periods.

(See "Mars," p. 24)

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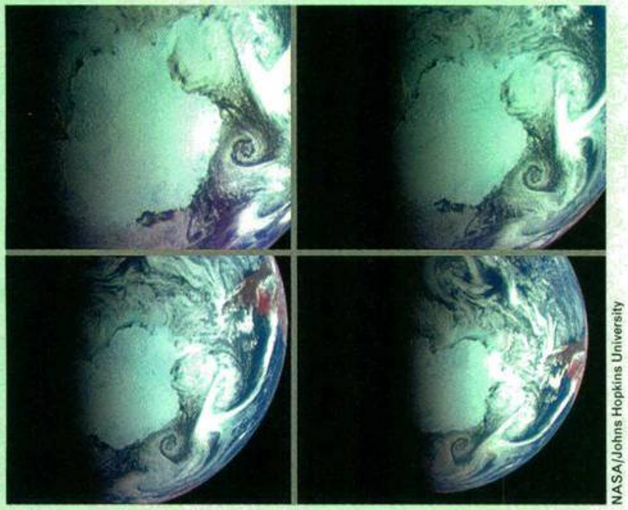
(Danger Zone)

extinctions seen in the fossil record during the last 600 million years match the dates of arm crossings. To check their numbers, they randomly generated 100,000 fake sets of dates for crossings and extinctions; only one percent of those produced a better match than the real data. "Virtually all extraterrestrial extinction mechanisms — asteroid impacts, nearby supernovae, passage through dust clouds — are enhanced by spiral-arm passage," says Leitch.

No need to panic just yet though. "The sun's position is 140 million years from the next spiral arm," says Vasisht.

— PAUL PARSONS

NEAR



NASA/Johns Hopkins University

RIGHT ON TARGET: Ice-covered Antarctica greeted the Near-Earth Asteroid Rendezvous (NEAR) spacecraft as it sped past Earth on January 23. NEAR showed up "right on schedule and right on target" according to Thomas Coughlin of Johns Hopkins University, which manages the mission. The flyby provided NEAR with a gravity assist that flung it out of the plane of the solar system and toward the near-Earth asteroid Eros. The spacecraft will enter orbit around Eros on January 10, 1999, when it will begin the first in-depth study of a near-Earth asteroid. It will ultimately land on Eros in February 2000.

Scientists used the flyby to calibrate NEAR's Multi-Spectral Imager and other instruments on known geological features on Earth and the moon. These false-color images were taken at 80-minute intervals as the spacecraft's distance from Earth increased from 92,000 miles (upper left) to 160,000 miles (lower right). The South Pole lies at the center of each image and features as small as eight miles across can be seen. Subtle shades of white and light blue denote sea ice and storm clouds surrounding Antarctica, while the reddish areas on the right of the lower two images represent vegetation in southern South America.

(Mars)

The most intriguing part of the new image shows a narrow channel cut by one final small flow through the system. This channel doesn't seem to be as eroded as the rest of the system, suggesting that a resurgent episode of water flow occurred long after the main channel had become dormant.

Mission controllers temporarily turned off the spacecraft's camera in mid-February to save energy.

— WILLIAM K. HARTMANN,
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HUBBLE SPACE TELESCOPE

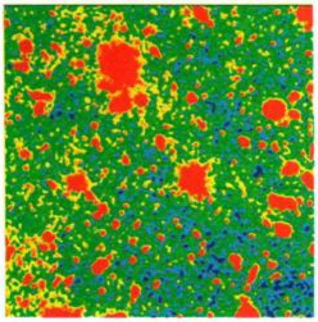
Darkness in the Deep Field

▶ The most enlightening astronomical photograph of 1996, the Hubble Deep Field image of some of the faintest galaxies ever seen in the cosmos (see "When Galaxies Were Young," May issue), now has a demonstrable dark side. Princeton University's Michael Vogeley searched between the polka-dot pattern of the Deep Field's faint galaxies and reported at the January meeting of the American Astronomical Society that all of the regions between the galaxies have a nearly uniform, smooth blackness.

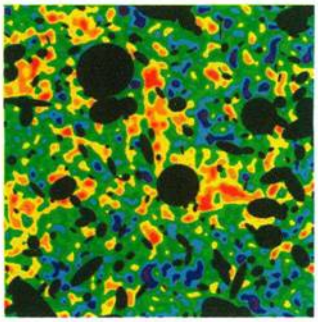
Vogeley found that — on galaxy-sized scales — light emanating from the Deep Field background varied by only one part per 1,000. If there had been large amounts of visible light from as-yet undetected galaxies, the Deep Field background should have been much lumpier with light. "The extraordinary smoothness of the background sky suggests that most of the visible light in the universe hails from galaxies that Hubble can detect," says Vogeley. In other words, the faint galaxies seen by Hubble could account for most of the visible light in the universe.

"A lingering question has been: 'Is a large fraction of the visible light hidden in lower surface-brightness galaxies that we simply miss with Hubble?' What this experiment shows," says Vogeley, "is that there is not a large amount of light in undetected objects."

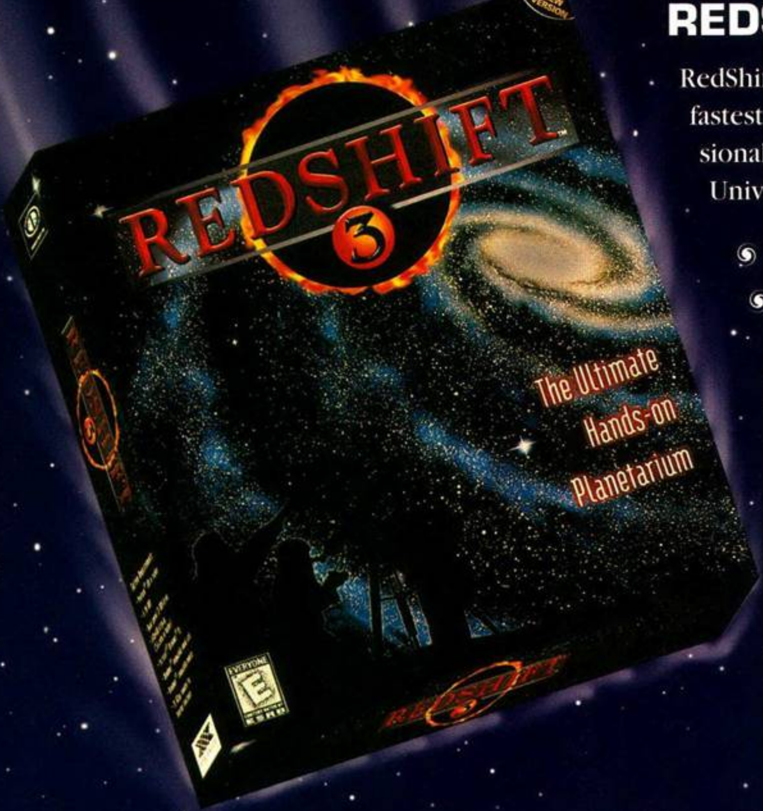
He cautioned, however, that dust clouds could be obstructing Hubble's view of more distant galaxies. If



ABOVE: This false-color close-up of the Hubble Deep Field shows galaxies (smallest red patches) that are four billion times fainter than what the human eye could see. **BELOW:** With the galaxies removed and the contrast boosted ten-fold, the faintest red patches are caused mostly by "noise" rather than by fainter galaxies. This means Hubble has accounted for most of the visible light in the universe. Michael Vogeley (Princeton University Observatory)



Meet Three Stars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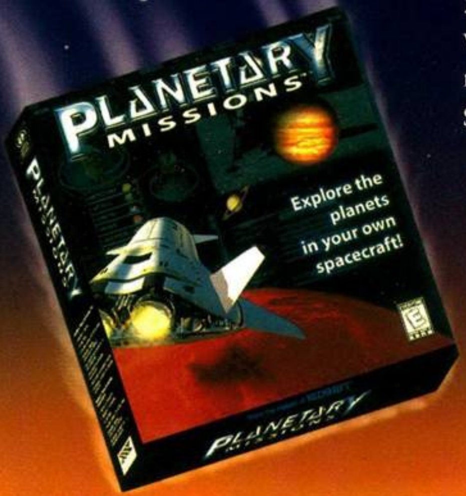
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visible light from such galaxies is blocked by dust, infrared radiation would still be able to pass through and be detected in infrared surveys. Evidence for this radiation was found recently by analysis of infrared sky maps made by the Cosmic Background Explorer satellite (see AstroNews, April 1996).

STAR BIRTH

The Tarantula's Scorching Lair

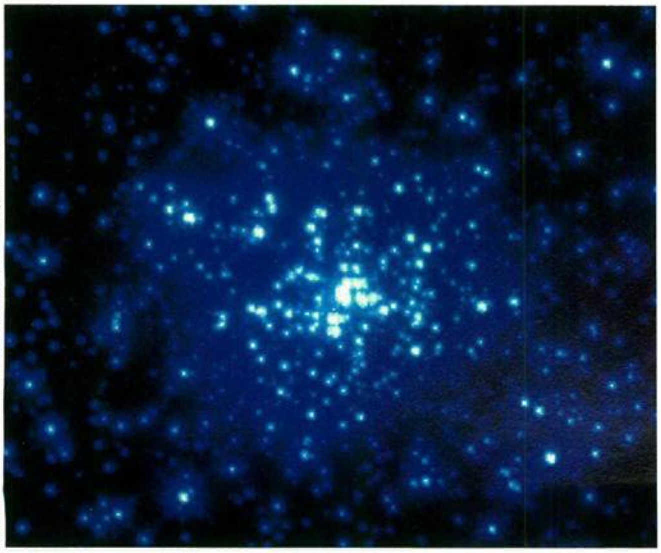
Home of the brightest and most massive stars

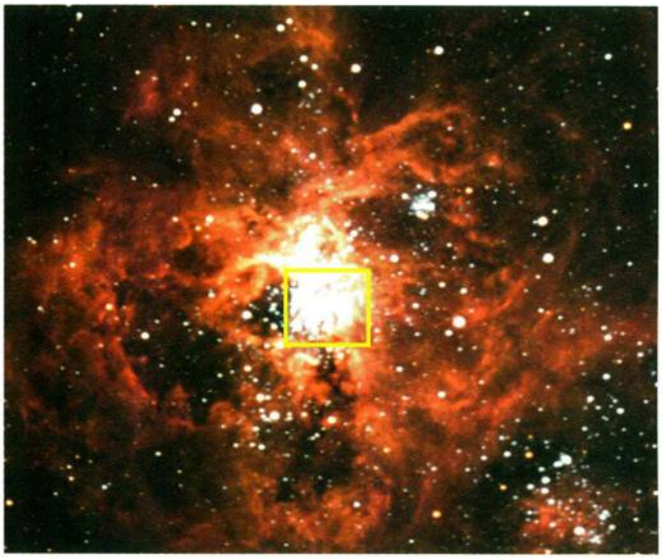
▶ Hear ye, future travelers of deep space: Avoid R136! This dense star cluster packs dozens of the hottest, most massive, and most energetic stars in the universe into a volume only 25 light-years across. The largest of these behemoths pump out the energy of 10 million suns, scorching the surrounding space with devastating x rays and ultraviolet radiation.

The cluster lies at the heart of the Tarantula Nebula, a gigantic stellar nursery in the Large Magellanic Cloud. From a safe distance of 163,000 light-years, Phil Massey of the National Optical Astronomy Observatories and Deidre Hunter of Lowell Observatory used the remarkable resolving power of the Hubble Space Telescope to obtain spectra of 65 of the brightest cluster members. Thirty-nine of the 65 belong to spectral class O3, reserved for the hottest and most luminous stars in the universe. These stars are so rare that astronomers now know more of them in R136 alone than in the rest of the universe combined.

About a dozen of R136's stars contain more than 100 solar masses, and the heaviest of the lot has about 150 solar masses. "This appears to be the most massive known star, period," says Massey. This star lies perilously close to the theoretical upper stellar mass limit. The nuclear furnace of a more massive star would be churning out so much light that the sheer pressure of its radiation would tear the star apart. But Massey proposes that if just one cluster could have so many stars so close to this limit, then nature's actual limit could be much higher. "Until we can look at even more extreme regions, we just won't know," he says.

The Tarantula Nebula's star cluster R136 is home to some of the most massive stars known.


Phil Massey (NOAO), Deidre Hunter (Lowell Observatory), and NASA


Andrew Peters

The Tarantula Nebula is a giant star-forming region 163,000 light-years away. If placed at the Orion Nebula's distance, it would fill half the sky and turn night into day. Hubble imaged the boxed-in area.

SOLAR ACTIVITY

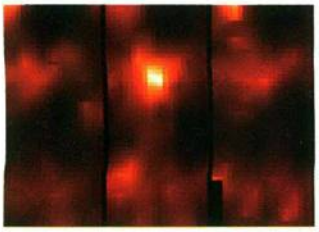
The Blinking Sun Gets Hot

▶ As solar physicists examine the sun in ever greater detail, it torments them with enigmatic events. Physicists dubbed their most recent surprise "blinkers," high-energy flashes that arise several thousand miles below the visible surface.

A team of astronomers led by Richard Harrison of the Rutherford Appleton Laboratory in the United Kingdom discovered blinkers with the European Space Agency's Solar and Heliospheric Observatory (SOHO). The team measured extreme ultraviolet radiation at different depths of the sun's atmosphere. "With our instrument, we were actually looking for microflares," said Harrison. "However, what we found was not quite what we expected. The blinkers are significant 'explosions' distributed like some disease over the entire sun. They may well be the most visible component of the events which lead to coronal heating and acceleration."

Blinkers may help explain two of the sun's biggest riddles — how the solar wind is generated and how the temperature jumps from 6,000° C on the surface to two million degrees in the

These pictures were taken a few minutes apart; before, during and after a blinker event.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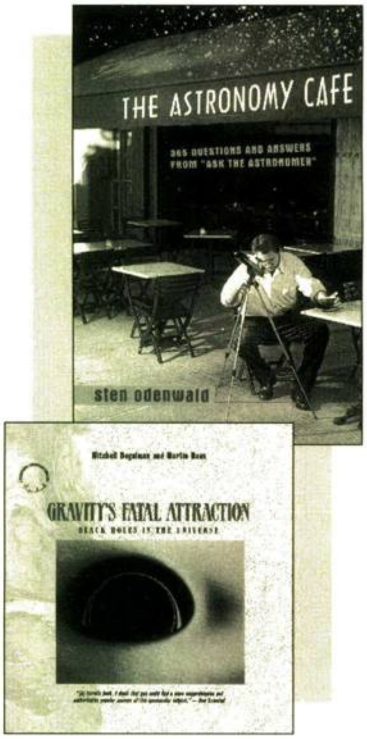
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outer corona. Harrison's team reported in the journal *Solar Physics* that blinkers might seem insignificant because each one emits only one-millionth the energy of a solar flare. But the sun has lots of blinkers. "There appear to be 3,000 at any point in time," said Harrison. Each blinker is Earth-sized and lasts about 10 minutes, but new blinkers burst to life as others fizzle.

EXTRASOLAR PLANETS

Planets Rising from the Ashes

Can a star's death lead to the birth of planets?

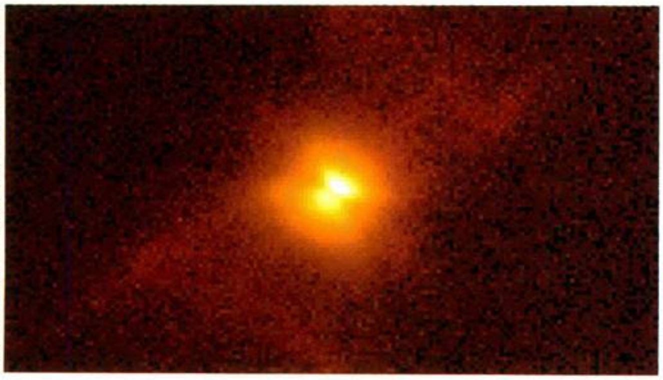
▶ It's common knowledge that planets form in disks of dust and gas that surround newly forming stars. But can planets also arise from the ashes of dead solar-type stars? According to a paper in the February 26 *Nature*, the answer is a surprising yes.

Using the European Space Agency's Infrared Space Observatory, Rens Waters of the University of Amsterdam and colleagues have found evidence that a thick, dusty disk surrounding a dying star is rich in oxygen-bearing minerals, including silicates. The dust grains are very similar to those in disks that surround newborn stars, where planet formation appears to be taking place.

The disk is embedded in a nebula known as the Red Rectangle, which consists of gas that a dying red giant star threw off in a vast stellar wind. The disk's formation is linked to a nearby stellar companion, which captured gas expelled from the red giant's equatorial plane and whipped it into a disk that surrounds both stars.

Are planets forming in the disk? Radio observations show that the dust grains have started aggregating into larger clumps. "We see the building blocks of planetesimals, but we can't say from our observations if there are larger bodies," says Waters. "However, the processes that led to planet formation in disks around young stars also seem to be at work in this disk." Waters says the disk won't be around long enough for Jupiters to form, but the process could give rise to smaller rocky planets. "It demonstrates that the processes that lead to planet formation happen wherever conditions allow it. It suggests that many stars may have planetary systems."

The Red Rectangle is en route to forming a planetary nebula. Planets could be forming in the dark disk between the two bright central areas.

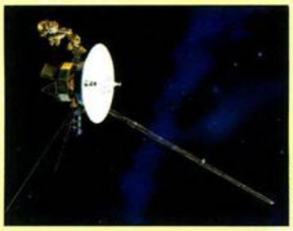


H. Bond (STScI), R. Ciardullo (Penn State Univ.), and NASA

Doomsday: October 26, 2028?

A one-mile-wide asteroid named 1997 XF_{11} enjoyed a Warholian 15 minutes of fame. On March 12, the media reported calculations by Brian Marsden of the IAU's Central Bureau for Astronomical Telegrams that the asteroid might pass within a hair-raising 30,000 miles of Earth (⅛ the Earth-moon distance) on October 26, 2028. The announcement spurred astronomers at the Jet Propulsion Laboratory to find prediscovery observations. Once some from 1990 were in hand, the asteroid's orbit was refined and astronomers realized that it would miss Earth by a comfortable 600,000 miles. Still, it has been added to the list of 108 "potentially hazardous asteroids."

Voyager 1 Is Far Out!



NASA/JPL

Voyager 1 has entered the record books as the most distant human-made object.

On February 17, 1998, Voyager 1 attained a distance of 6.5 billion miles from Earth (10.4 billion km, or 70 astronomical units), making it the most distant human-made object. The previous record holder was Pioneer 10, which is heading in almost the opposite direction at a slower speed. Launched on September 5, 1977, Voyager 1 flew by Jupiter on March 5, 1979, and Saturn on November 12, 1980. Voyager 1 continues to return data on the solar wind and magnetic field, and it should have enough electricity to operate until 2020.

How Big Are Giants and Supergiants?

Astronomers using the Palomar Testbed Interferometer (PTI) have measured the radii of 70 giant and supergiant stars. These highly evolved stars, which swelled up when their cores ran out of hydrogen fuel, range from 10 to 300 times the diameter of the sun. With two telescopes separated by 360 feet (110 meters), the PTI yields a resolution equal to that of a 360-foot telescope. The astronomers used the interferometer to measure the angular sizes of the stars, then combined those with distances determined by the Hipparcos satellite to calculate the radii.

New Mission to Europa

President Clinton has included funding for a Europa orbiter in his proposed 1999 NASA budget. Europa Orbiter, planned for launch in 2003, would include a radar sounder to bounce radio waves through the surface ice to find out where the ice stops and where a possible water ocean begins. Other instruments would map the moon's entire surface to a resolution of a few hundred feet. The spacecraft could serve as a precursor to sending "hydrobots" or remote-control submarines.

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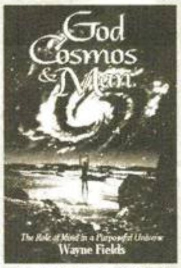

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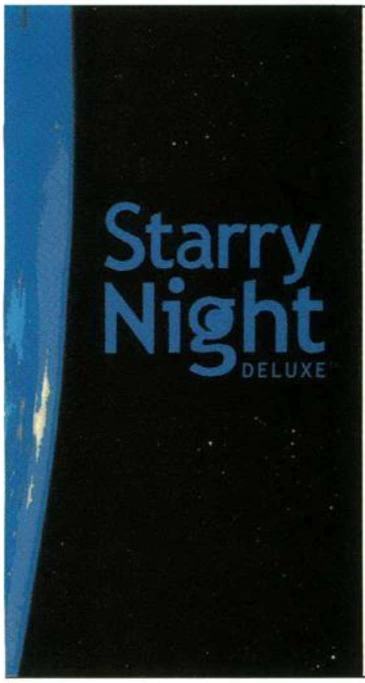

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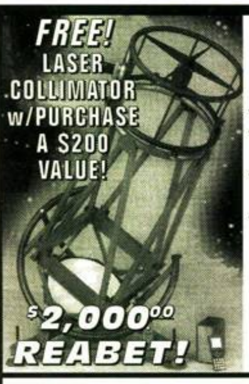

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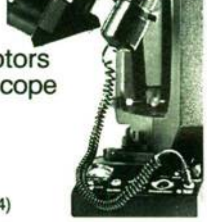

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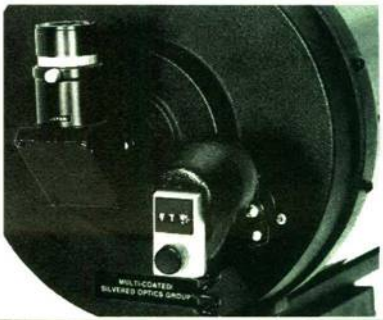

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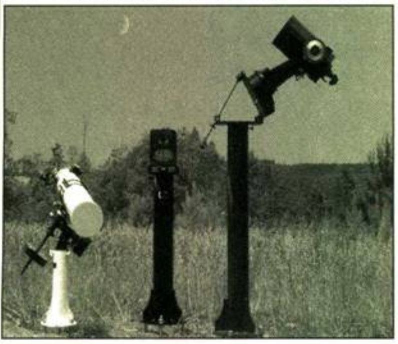

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ask Astro

Buying a Telescope, Aurorae, NASA's Next Mars Mission

In December 1997 the editors of *Astronomy* received a delightful surprise in the mail: 100 questions for Ask Astro from senior astronomy students at Lyons Township High School in La Grange, Illinois. Because the students asked such interesting and diverse questions, we have decided to devote this month's Ask Astro to their queries. We thank the students' astronomy teacher, Kevin Murphy, for his encouragement.

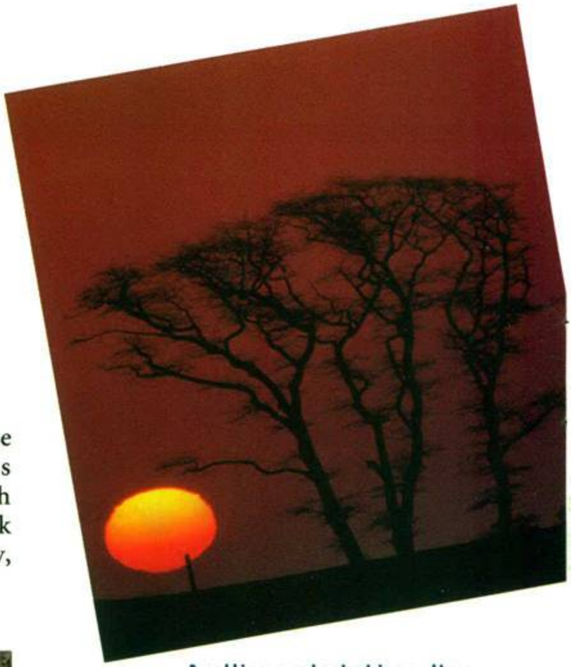
Craig Stillwell / Adler Planetarium & Astronomy Museum

Q: What kind of telescope would you recommend for an amateur astronomer just starting out? — *Marie Olson*

A: Keep it simple. If you buy something loaded with complex bells and whistles, you're liable to wind up spending more time in front of an owner's manual than under the stars. That first telescope should extend a beginning skygazer's most powerful tool: the unaided eye. It could be a pair of binoculars — just lift and view. A beefier alternative is Edmund Scientific's round-bottomed, $4\frac{1}{8}$-inch Astroscan 2001, which sets up on a table top or photo tripod. Bigger still are the Dobsonian-type telescopes that sell for under $500, with larger mirrors that gather more light so you can see fainter targets with greater detail. Beware of inexpensive telescopes that advertise high power. Whatever you settle on, walk before you run. Learn the lay of the heavens and the location of its treasures. — *John Shibley*

Q: Why does the sun appear larger when it is setting? — *Shannon Cleary*

A: When near the horizon, the sun certainly seems bigger — and so do all celestial objects, at least those with a perceptible angular size. Stars are dots, so they don't appear to change. But as for constellations, look at the Big Dipper the nights when it scrapes the skyline just before dawn — it's no longer the Big Dipper, it's the Humongous Dipper.



A setting sun looks bigger than normal, but it really isn't. Larry Landolfi

Is it the thicker horizon atmosphere that inflates the sun, moon, and constellations — as if air can act as some kind of funhouse lens? No. Thick air can distort things — look at the grotesque squashed shapes assumed by the setting sun — but it doesn't make anything appear larger.

The seeming size increase is merely an illusion, a natural hoax. It's a psychological effect that comes from our lifelong experience that things near the horizon are far away and thus must be large if we're seeing them at all. The illusion also results from the juxtaposition of the celestial object near familiar earthly landmarks such as distant trees or houses, which gives them dimensionality. When high in the heavens, the tiny half-degree sun and moon are dwarfed by the immensity of the 180° hemisphere of the sky. That it's really always the same size can be proven by viewing the moon through a cardboard tube when it's low and again when it's high. You'll see that it appears the same size in both cases. — *Bob Berman*

Q: What causes the Northern Lights? — *Kelly McMillin*

A: The Northern Lights, or aurora borealis, arise when charged subatomic particles (protons and electrons) from the sun react with gases in Earth's upper atmosphere. The sun continually releases these particles in a discharge called the solar wind. Earth's magnetic field captures some of the particles, collecting them in doughnut-shaped magnetic regions called the Van Allen belts. The solar wind normally sweeps around Earth's outer atmosphere. As it does, it builds up a charge of more than 100,000 volts between the magnetic field and the atmosphere. This forces some of the charged particles out of the Van Allen belts and funnels them into the atmosphere at the north and south magnetic poles. The ions spiral downward, exciting the gases they encounter into a glowing frenzy.

Because this stream of solar particles is continual, people living near the north and south magnetic poles can see an aurora on nearly every clear night. To see these at lower latitudes, we need a large solar storm, or flare. When the sun has a major eruption it releases huge quantities of charged particles, creating a "gust" in the solar wind. When the particles reach Earth, they swamp the Van Allen belts and pour into the atmosphere. The huge influx of particles creates an awe-inspiring display that can pulsate and shimmer along Earth's magnetic field lines.

The most common type of aurora is a curtain of green caused by charged particles hitting oxygen atoms some 60 miles high. Slower particles that don't travel deeply into the atmosphere cause red aurorae by hitting atoms 120 miles up. Green aurorae with red fringes are a mixture of the two. Highly energetic particles can travel deeper into the atmosphere to create a red base to the common green curtain. These particles are reacting with nitrogen some 45 miles up. — *Andrea Gianopoulos*

Green aurorae are the most common, resulting from charged particles hitting oxygen atoms in Earth's upper atmosphere.

Michael Klensch

Q: Why do some planets have more moons than others? — *Maribeth Gaffner and Nick Lundin*

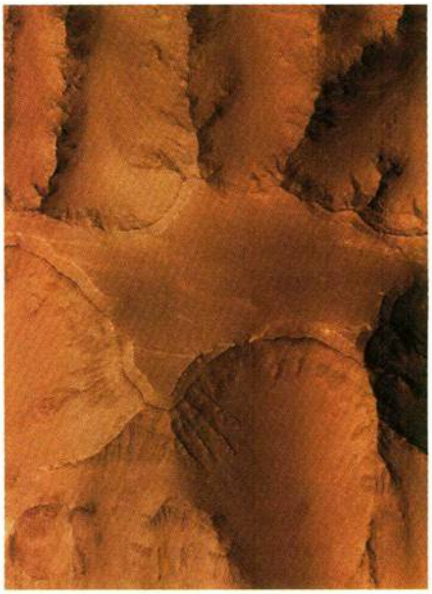
A: The number of moons varies from planet to planet because the planets formed by a variety of different processes. The giant planets apparently had so much gravity that large disks of dust, ice grains, and gas formed around them. Whole families of satellites formed within these disks, just as the planets themselves formed in a disk around the young sun.

The smaller terrestrial planets, having much weaker gravity, did not form such disks. Mars apparently captured two asteroids as satellites. Earth got a large satellite when it was hit by another growing planetary body, which blasted material out of is upper rock layers, from which the moon formed. — *William K. Hartmann, Planetary Science Institute*

Q: Out of the nine planets in our solar system, which one most resembles Earth or is most likely to have signs of life? — *Courtney Ryan*

A: There are actually two answers to this question. Venus is almost an Earth-twin in its general size and mass, but it is not very Earth-like in its environment. Its massive carbon dioxide atmosphere causes a greenhouse effect that heats the surface to about 900° F (480° C) — not a place to visit for your summer vacation.

Certainly the most Earth-like planet in terms of surface environment is Mars, with its dusty, cold deserts. Summer afternoon air temperatures reach just above freezing. Mars has many Earth-like features, including clouds, polar ice caps, sand dunes, dry riverbeds, and volcanic landforms. The new Mars Global Surveyor photos from Mars orbit reveal a landscape reminiscent of airplane photos of parts of Arizona, New Mexico, Nevada, and Utah. — *William K. Hartmann*

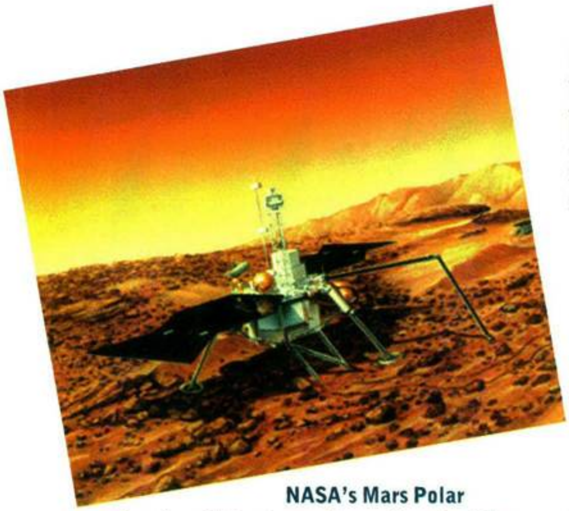


High-resolution Mars Global Surveyor images such as this reveal a landscape reminiscent of the American desert Southwest. Malin Space Science Systems/NASA

Q: Are there any other landings planned for Mars within the next few years? — *John Kneller*

A: Yes. NASA will launch a lander in January 1999, recently named the Mars Polar Lander. It will touch down near the edge of the martian south polar cap in December 1999, providing images and data from a region of Mars very different from the Viking and Pathfinder sites.

Unlike Mars Pathfinder, this lander will not carry a rover, but it will have a small robotic arm that can scoop up underground soil samples to look for water ice and evidence of past climate change. The lander will also carry a descent camera, which will take spectacular images as it plunges through the atmosphere. Mars Polar Lander also includes a microphone for recording sounds on Mars. Before it enters the atmosphere, the spacecraft will release two 4.5-pound (10 kg) torpedo-shaped



NASA's Mars Polar Lander will land near the south pole of Mars in December 1999. NASA/JPL

penetrators that will impact the martian surface about 60 miles (100 km) north of the landing site.

In December 1998, NASA will launch an orbiter called Mars Climate Orbiter, which will reach the Red Planet in September 1999. NASA plans to launch both an orbiter and a lander to Mars every 26 months, when Earth and Mars line up, so a mission can be accomplished with the least amount of fuel. If all goes according to plan, NASA's Mars program will culminate in a sample-return mission that will launch in 2005. — *Robert Naeye*

Q: Can you put into proportion the distance from Earth to the sun using something that is conceivable on Earth?

— Steven Beranek

A: There are several ways to think of the average Earth-sun distance, which is 93,000,000 miles (150,000,000 km) in raw numbers. I like to think of the sun as being eight light-minutes away, meaning it takes light eight minutes to cross the void between the sun and Earth (which also means that if the sun suddenly vanished, we'd have eight minutes to live). That same beam of light could circle Earth 7.5 times in one second. In other words, you'd have to go around Earth about 3,600 times to travel the Earth-sun distance.

Another way of looking at it is to think of Earth as being the size of a pea (0.04 inch or one mm across). The sun would be the size of a beach ball about one-third of a mile (0.5 km) away.

If you were driving a car at 60 miles (100 km) per hour non-stop, it would take you 177 years to reach the sun. If you were traveling in a jet airliner at 500 miles (800 km) per hour non-stop, it would take 21 years. Personally, I'd rather go to Tahiti.

Of course, the sun's distance is nothing compared with the distances to the other stars. If you put Earth one inch from the sun in a scale model, the next nearest star (Proxima Centauri) would be 4.2 miles (6.8 km) away (see "Interstellar Trekking," page 46). — *Robert Naeye*

Q: Does the gravitational force of a black hole have an effect on space-time?

— Nicole Milan

A: Yes, the gravitational force of a black hole affects space-time. Space is normal far from any massive object, so the geometry you learned in high school works just fine. But massive objects warp space-time, and the geometry of curved space, Riemannian geometry, named for the 19th-century German mathematician and physicist Georg Friedrich Riemann, must be used to calculate distances, angles, and the motions of particles. The larger the gravitational field, the more distorted the geometry becomes.

Black holes such as the one inside the quasar in this painting will "warp" the surrounding fabric of space-time, like a bowling ball placed on a soft mattress. Adolf Schaller

The gravitational field of a black hole is so strong that deep within it lurks a singularity, a point where not even Riemannian geometry works. Our understanding of singularities is incomplete, so your homework assignment, Nicole, is to develop a new type of geometry (which we'll call Milanian geometry) to account for singularities. Because this is a very hard problem, you can take the rest of your life to work on it. — *Rocky Kolb, Fermilab*

Q: If there is a black hole in the middle of our galaxy, approximately how long will it be until Earth is pulled in?

— Rebecca Rutkowski

A: Surprisingly, not even our distant descendants will have to worry about this less-than-appealing fate. According to Newton's law of gravity, the pull of a black hole depends only on its mass and its distance from us. A black hole at the center of our galaxy would have no more effect on us than a huge star cluster having the same mass.

In the same way, if a black hole with the sun's mass replaced our sun, Earth would continue to orbit the black-hole sun just as it does now. (Although it would quickly get *a lot* colder!) A black hole's reputation for immense gravity comes from the fact that you can get much closer to it. A black hole with the sun's mass would be only a couple of miles across — compared with the sun's 864,000-mile diameter — and that factor of about 100,000 translates into a 10 billion-fold increase in the gravitational pull near the surface of such a black hole. — *Richard Talcott*

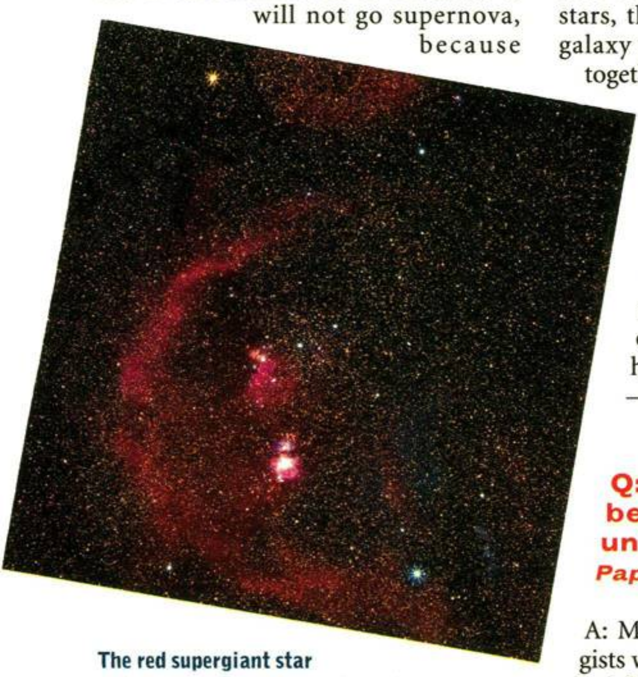
Q: What is a quasar?

— Cheryl Martin

A: Quasars are brilliant points of light and radio radiation at extraordinary distances, some lying near the limit of the visible universe. They are now thought to be the ultrabright nuclei of very active galaxies that somehow feed matter into supermassive black holes, the hot mass surrounding the black hole acting as the visible quasar. Because they are all so far away, the quasar appears to be an early stage in the evolution of certain, but unknown, types of galaxies. — *James Kaler, University of Illinois*

Q: Do astronomers have any educated guesses about when Betelgeuse or Arcturus will go supernova? How bright will they be? — *Jeff Bloom, Dan Veeser, Matthew Vonachen, Scott Lutzow*

A: Like most answers, I will say yes and no. First, a definite no to Arcturus. It will not go supernova, because it does not have sufficient mass to build the required iron core. Arcturus is a helium-burning giant, and it will die a relatively gentle death. Its outer layers will form a planetary nebula, while the core will become a white dwarf.



The red supergiant star Betelgeuse — which is destined to go supernova — marks the upper-left shoulder of Orion. Tony and Daphne Hallas

With about 20 solar masses, Betelgeuse is a different matter. We can calculate with some accuracy how long such a star will live from birth to explosive death, but we have no idea where the star is right now in its internal nuclear burning stages. We can estimate that it will go off sometime within the next million years. But we could also see it go off tonight! If it went off at its present distance, Betelgeuse would shine at about magnitude –9, 100 times brighter than Venus at its brightest, meaning it would rival a crescent moon. — *James Kaler*

Q: Because all the planets and our sun exert a gravitational pull on one another, is there any place outside the solar system that would be free of any gravitational forces? — *Moira Jurcik*

A: No. Isaac Newton discovered that the gravitational force of any body extends to infinity, to forever. The gravitational force drops off quickly as you leave a body's vicinity, but it never falls to zero. In the spaces between stars, the combined gravity of all the galaxy is enough to keep the galaxy together and to make the stars orbit its center. In the spaces between galaxies, the force keeps clusters of galaxies together. The force is so potent that it can slow the expansion of the entire universe, and if there is enough matter in the universe, it could even bring the expansion to a halt and start it contracting. — *James Kaler*

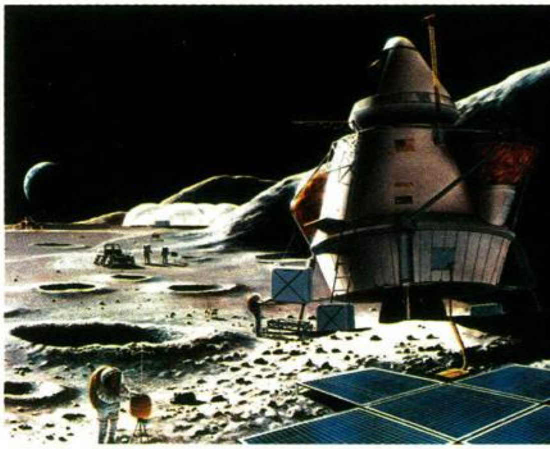
Q: Is there anything beyond the edge of the universe? — *Bethany Pappalardo*

A: Most astronomers and cosmologists would answer no — the universe is defined as everything that exists, so there can be no such place as "beyond" the universe. But there is an edge to the observable universe. We can see a galaxy, for example, only if enough time has passed since the Big Bang for its light to have reached us. A galaxy farther away would currently be beyond our horizon, or outside the observable universe. Only after more time elapses will it come within our cosmic horizon. — *Richard Talcott*

Q: Is it possible for human beings to live on the moon? — *Bill Haas, Kevin Johnson, and Krissy Sumanas*

A: NASA has done many studies to determine the feasibility of establishing a lunar colony. The conclusion: Anything is possible. But there is no set timetable for going back to the moon: Such a venture will be expensive, so it will have to be a decision made by the American people.

The Apollo astronauts went to the moon, spent a few days collecting samples, and then came back. So the next logical step is to have people stay on the moon and establish a long-term human presence. Such a venture will allow us to gain valuable experience for future manned planetary exploration, including possible missions to Mars.



Humans may someday set up permanent habitats on the moon. Pat Rawlings/NASA

The moon has some of the raw materials necessary to sustain life, including oxygen and water ice (as recently discovered by Lunar Prospector, see page 20). By mining and refining these substances, colonists can use on-site materials for living and rocket fuel, which is much cheaper and safer than hauling these materials up from Earth. NASA has also been conducting on-going studies to see if future colonists can grow plants in lunar soils. The results to date have been encouraging. In summary, studies have shown that establishing a lunar colony is certainly feasible, as long as the inhabitants can take advantage of local resources. — *James Hartsfield, NASA/Johnson Space Center*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

LOOK

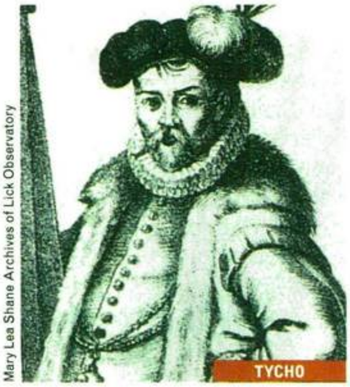
THE A LIST:

These 25 extraordinary individuals, though now gone, helped change our view of the cosmos.

- *Early in the 20th century, American Walter Adams deduced the luminosities and distances of stars from their spectra and discovered that the companion to Sirius was a white dwarf star.*

- *During the 1940s, German-American Walter Baade showed that the Andromeda Galaxy's spiral arms contained young stars and its nucleus old ones; he also recalibrated the distance scale for Cepheid variable stars.*

- *The 16th-century Dane Tycho Brahe produced the accurate positions Kepler needed to deduce the laws of planetary motion.*



TYCHO

Mary Lea Shane Archives of Lick Observatory

- *In the early 1900s, American Annie Jump Cannon developed the scheme for classifying stellar spectra that, with few changes, is still used.*

- *In the 1600s, Italian-French observer Giovanni Cassini first measured the solar system's scale; he also found four moons of Saturn and the division in its rings.*

- *In the 1930s, Indian-American theorist Subrahmanyan Chandrasekhar elucidated the structure of white dwarfs and deduced that they could not exceed 1.4 solar masses.*

- *In 1543, Polish astronomer Nicolas Copernicus published his revolutionary model of the universe placing the sun at the center instead of Earth.*

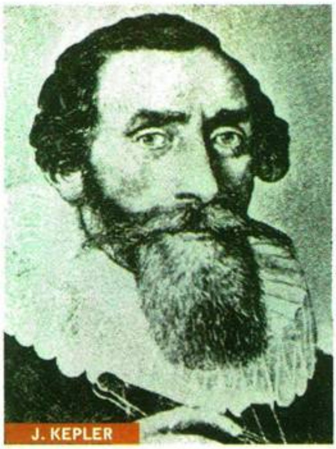
- *In the first part of this century, English astronomer Arthur Eddington developed the theory of stellar interiors and deduced that more massive stars are brighter.*

- *In the 1910s, German-American physicist Albert Einstein developed general relativity, the best theory we have for describing the structure and evolution of the universe.*

- *In the early 1600s, Italian Galileo Galilei used a telescope to peer at the heavens for the first time, discovering lunar craters, the moons of Jupiter, and the phases of Venus, all of which suggested Copernicus was right.*

- *At the turn of this century, American George Ellery Hale invented instruments for viewing the sun and discovered magnetic fields in sunspots, but he is most remembered for being the driving force behind Yerkes, Mt. Wilson, and Palomar observatories and their giant telescopes.*

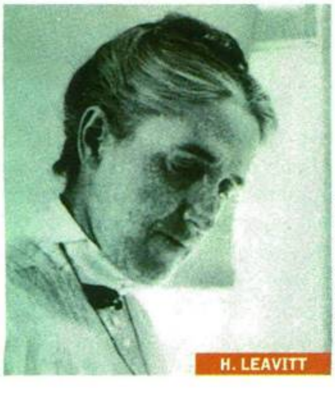
- *In the 1780s, the German-English observer William Herschel discovered the planet Uranus, its moons Titania and Oberon, and Saturn's moons Mimas and Enceladus. He also discovered more than 800 double stars and showed that many were bound by gravity, the first evidence that Newton's laws held outside the solar system.*



J. KEPLER

Mary Lea Shane Archives of Lick Observatory

- *In the early 1900s, the Dane Ejnar Hertzsprung and American Henry Russell independently found the relation between a star's color and its luminosity.*



H. LEAVITT

Harvard College Observatory

BACK

HISTORY'S GREAT ASTRONOMERS

- *In the second century B.C., Greek astronomer Hipparchus developed the magnitude scale, compiled a detailed star catalog, discovered the precession of the equinoxes, and accurately measured the moon's distance.*

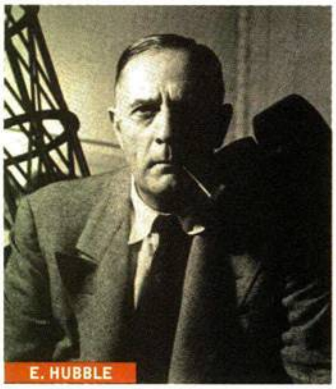
- *In the 1920s, American Edwin Hubble discovered Cepheid variables in the Andromeda Galaxy and showed this galaxy to be outside our own; he then found that distant galaxies are rushing away from us, showing that the universe is expanding.*

G. KUIPER

Yerkes Observatory

- *In the early 1600s, German theorist Johannes Kepler devised three laws that explain how the planets move in the solar system.*

- *In the middle of the 20th century, Dutch-American astronomer Gerard Kuiper sparked a rebirth in planetary science; he discovered Uranus's moon Miranda, Neptune's moon Nereid, and, most important, an atmosphere surrounding Saturn's moon Titan.*



E. HUBBLE

Carnegie Observatories

- *In the late 18th and early 19th centuries, French astronomer Pierre Simon Laplace established the basic stability of the solar system through the use of celestial mechanics and then developed the still-accepted hypothesis that the planets of the solar system condensed out of a nebula.*

- *In the 1910s, from observations of the Large Magellanic Cloud, American Henrietta Leavitt discovered the period-luminosity relation for Cepheid variable stars, a cornerstone in measuring distances in the cosmos.*

- *The 17th-century Englishman Isaac Newton developed the laws of motion and of universal gravitation; he also invented the first workable reflecting telescope.*

- *The 20th-century Dutch astronomer Jan Oort mapped the spiral structure of our galaxy and accurately deduced its size; he also suggested that comets reside in a giant cloud lying well beyond the planets.*

- *In the 1920s, American Cecilia Payne-Gaposchkin deduced the relationship between a star's spectral class and its temperature and determined the structure of stellar atmospheres.*

- *In the 1910s, American Harlow Shapley studied the distribution of globular clusters in our galaxy, yielding a rough size for the galaxy and placing Earth well away from the center.*

- *Beginning in the 1920s, the Russian-American astronomer Otto Struve helped pioneer the study of binary star evolution and the composition of the interstellar medium.*

- *In the mid-20th century, Swiss astronomer Fritz Zwicky deduced the existence of dark matter from observations of galaxy clusters; he also studied supernovae and predicted that they could produce neutron stars.*

Astronomy
25
YEARS

jumping jupiter

The Galileo spacecraft has sharpened our view of the solar system's largest planet and its four largest moons.

by Richard Talcott

WHEN THE VOYAGER 1 AND 2 SPACECRAFT flew past Jupiter in 1979, they revealed a giant planet with intricate weather patterns circled by four startlingly complex moons. Racing by at 30,000 miles per hour, the Voyagers got only a brief look at the jovian system. However, it was time enough for the spacecrafts to discover huge, active volcanoes on the moon Io, an icy cue-ball smooth surface on Europa, bizarre grooved terrain on Ganymede, and wall-to-wall craters on Callisto. How could Jupiter's large moons be so different? As is often true of astronomy, the observations of these four largest of Jupiter's 16 moons — the so-called Galilean satellites — raised many more questions than the Voyagers answered.

Enter the Galileo spacecraft. From its rendezvous with the jovian system in December 1995 until its flyby of Europa in November 1997, the spacecraft enjoyed a spectacularly successful primary mission. In all, Galileo made 11 orbits around Jupiter: During that time it provided planetary scientists with close-up views of Jupiter and the Galilean moons and helped answer many of the questions raised by the Voyagers.

The spacecraft found strong evidence that an ocean of liquid water, or at least slushy ice, exists beneath Europa's icy surface. Galileo also furnished the first photos showing widespread changes on the volcano-ravaged surface of Io. Earth is the only other place in the solar system with liquid water and the only place, so far, where life is known to exist. One of the most important questions raised by the jovian moon's watery and geologically active subsurface is whether chemical ingredients similar to those found in Earth's life-sustaining, deep oceanic ridges exist under Europa's shroud of ice.

Galileo also made the first observations of the atmospheres and interiors of the Galilean moons and of thunderstorms on Jupiter that help power huge storm systems.

The end of Galileo's primary assignment in December 1997 didn't mean the spacecraft was finished. NASA extended the mission for two more years (see "Galileo's Extended Life," page 42) to follow up on its earlier discoveries, particularly those hinting at water on Europa. The first flyby of the renamed Galileo Europa Mission came on December 16, 1997, when the spacecraft made its closest approach to Europa, marking the first of more than a dozen flybys scheduled through the end of 1999.

Europa's Puzzling Surface

The first inkling that something unusual was up with Europa came from photographs showing a remarkably smooth surface nearly devoid of large craters. Although that much was visible to the Voyager cameras, those spacecraft never came close to Europa: Even at their closest approach to Europa, the Voyagers remained several hundred times farther from the moon than Galileo did during its flybys.

Galileo quickly confirmed the paucity of big impact *craters, proving the youth of* Europa's surface. Because the meteorites and comets that create craters fall at a relatively constant rate, the

Volcanic Io, icy Europa, grooved Ganymede, and cratered Callisto *(shown from top to bottom)* may be complex worlds in their own right, but they are dwarfed by Jupiter and its Great Red Spot.

All photos NASA/JPL

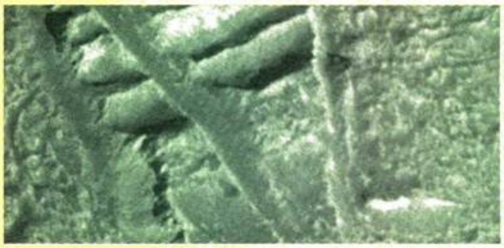
Galileo's Extended Life

The Galileo Europa Mission (GEM) got off to a rousing start with the closest ever flyby of Europa on December 16. But that was just the first of more than a dozen new encounters with Jupiter and its moons to come during the next two years.

The mission consists of a Europa campaign, a "perijove reduction campaign," and an Io campaign. The Europa part of the mission features eight close flybys of the icy moon. The main goal is to search for more evidence of a subsurface ocean by looking for possible ice volcanos and using gravity measurements to probe the moon's interior.

The perijove reduction campaign calls for four flybys of Callisto that will cut in half the spacecraft's closest distance to Jupiter, or perijove. The campaign, which will last for six months in mid-1999, features few observations of Callisto. Instead, Galileo will look at water in Jupiter's atmosphere and view the Io torus, a donut-shaped region of charged particles that circles Jupiter in Io's orbit.

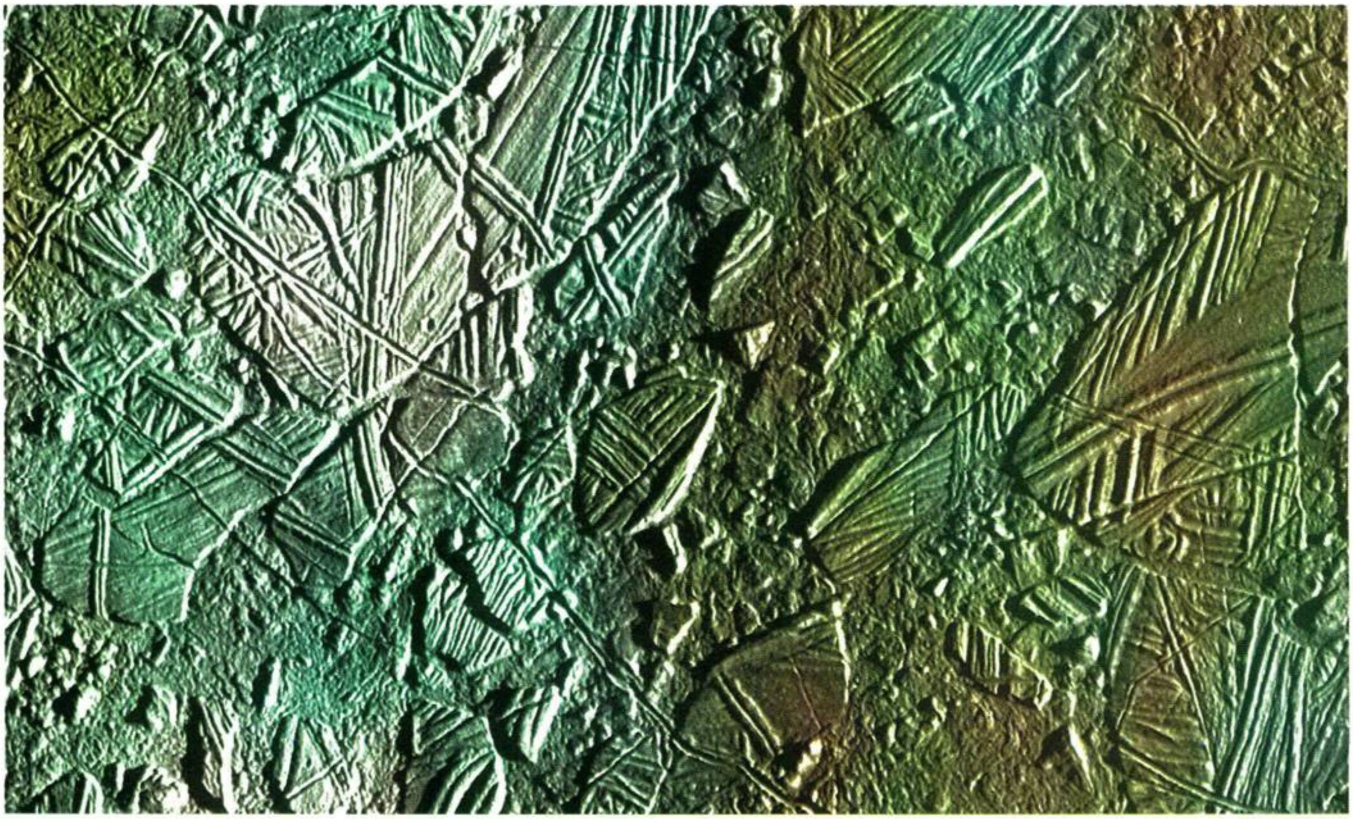
GEM wraps up with what could be one of the highlights of the entire Galileo project: two close flybys of Io. Skimming just a couple hundred miles above the surface, Galileo will survey the fiery moon in unprecedented detail and even fly through the plume of the Pillan Patera volcano.



Steep cliffs mark the edges of ice plates in Europa's chaos terrain in this view from the first GEM flyby.

A major question: Can the spacecraft survive the extended mission? Although Galileo has plenty of power left and more than enough fuel, its tape recorder has already exceeded some of its design limits. And a hardware problem in one of two gyroscopes may hamper the craft's pointing ability. That glitch seems to be radiation induced, and radiation levels will only get higher as GEM progresses and Galileo gets closer to Jupiter.

Europa's thin, disrupted ice crust shows well in the Conamara region. The white and blue colors are areas blanketed by fine ice particles from the impact that created the crater Pwyll 600 miles to the south.



smooth surfaces indicate that a process must be at work erasing evidence of the impacts.

But Galileo provided far more clues about this active process on Europa. Close-up images showed evidence of ice flows, a complex network of crisscrossing ridges, and blocks of ice that appeared as though they may once have floated across the surface like Arctic icebergs. These ice formations added to the evidence that a liquid ocean once sloshed beneath the frozen surface.

"These blocks of ice appear similar to those seen on Earth's polar seas during springtime thaws," says Arizona State University planetary scientist Ronald Greeley, a member of the Galileo imaging team. "The size and geometry of these features lead us to believe there was a thin icy layer covering water or slushy ice, and that some motion caused these crustal plates to break up."

Complex tectonic activity created this 50-mile-wide feature on Ganymede. The lens shape probably arose when one area slid past another and also rotated slightly.

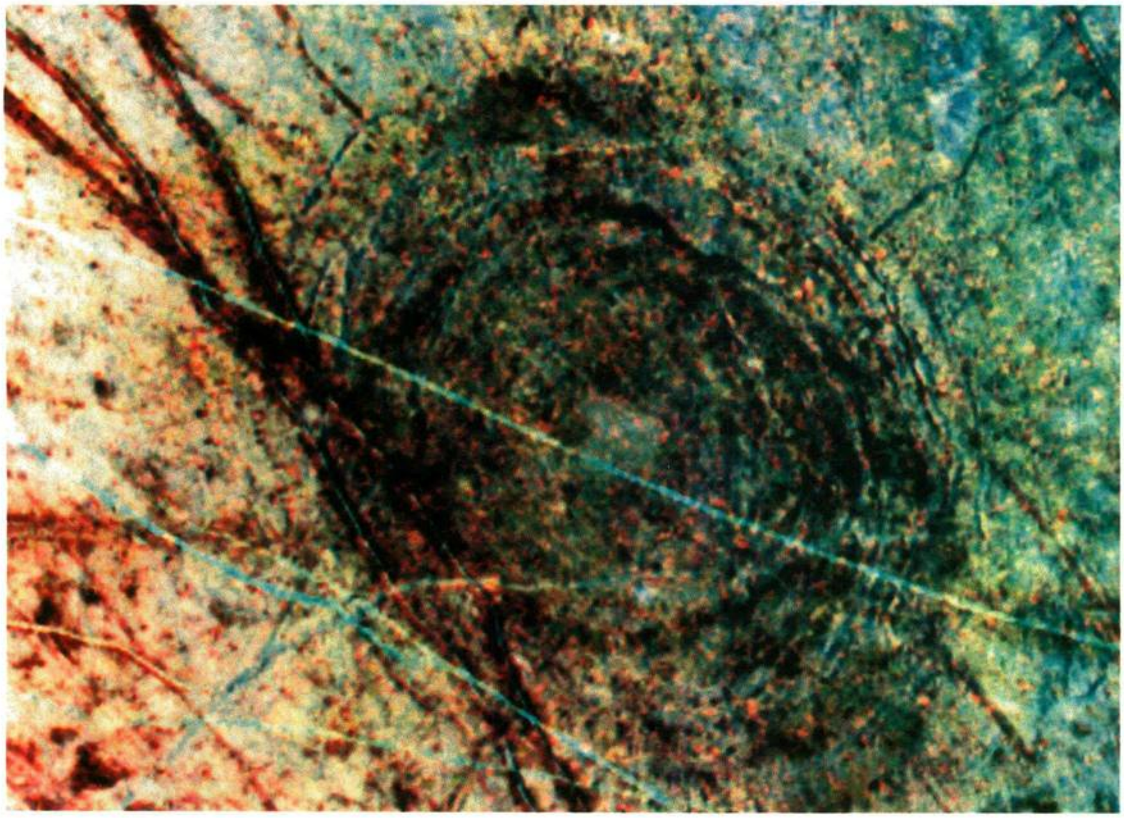
Liquid water may seem an odd substance to encounter in Jupiter's vicinity, where the temperature hovers at a frigid –260° F and would freeze an ocean solid in just a few million years. Therefore something in the recent past must have heated Europa's interior enough to melt, or at least soften, the ice.

Unlike Earth, whose interior remains molten because of the heat-producing decay of radioactive elements, Io, Europa, and Ganymede are heated by a gravitational tug-of-war with their parent planet. The gravitational pull of massive Jupiter combines with the smaller influence of the other Galilean satellites to raise tides in the solid bodies of the moons. These tides flex and stretch the moons to generate heat.

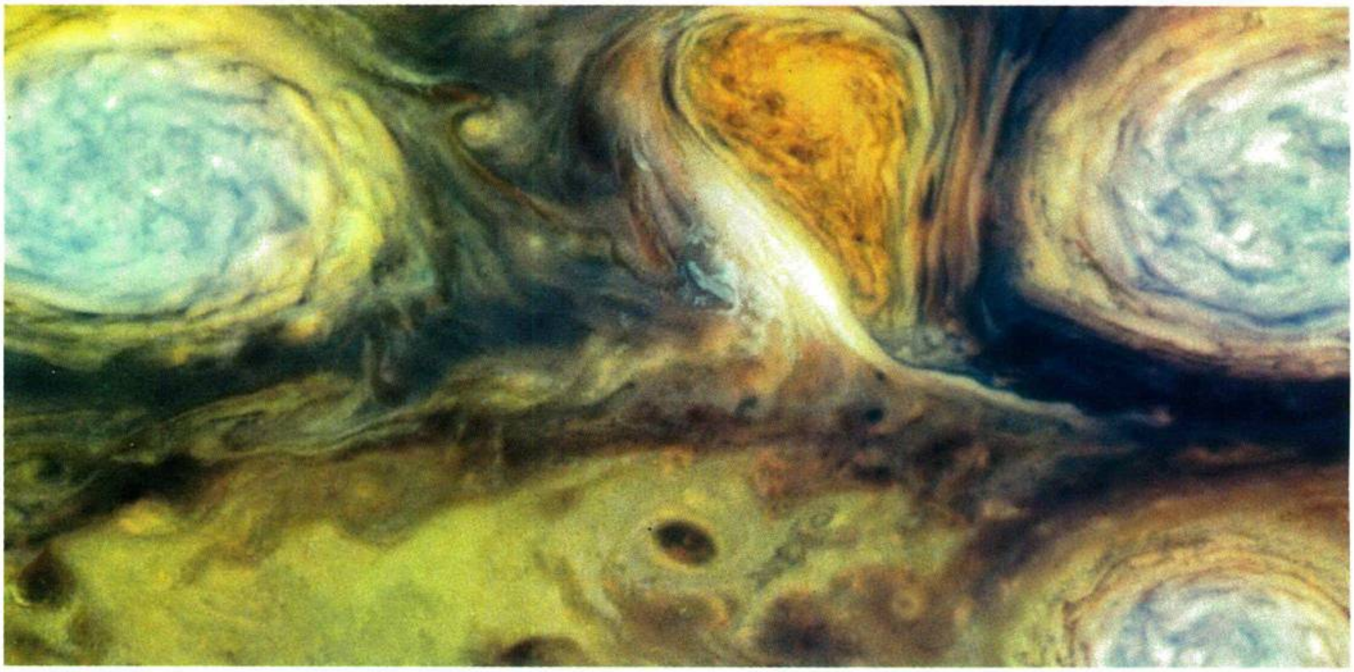
The Closest Look Yet

The images taken in the first flyby of the extended mission provided the closest views of Europa that Galileo will ever get. Skimming just 125 miles (200 km) above the moon's surface last December, Galileo returned images showing details as small as 20 feet (6 m) across. The new photos provide three additional pieces of evidence for a wet interior.

Looking at the debris pattern surrounding the only large, recent impact site on Europa, the 16-mile-wide (26 km) crater named Pwyll, researchers concluded that the impact occurred just 10 million to 100 million years ago. If the impact object had struck either rock or solid ice, the crater would have retained its initial size and shape over this geologically brief period. Instead, Pwyll has a very



This bull's-eye impact crater on the surface of Jupiter's moon Europa shows concentric fractures in the icy surface that cover an area the size of Hawaii.



Jupiter's atmosphere roils with cyclonic activity. In this false-color image, a balloon-shaped vortex rotates between two white ovals that formed in the 1930s.

shallow basin and a high central peak — just what you'd expect if the subsurface ice was warm enough to collapse and fill in the deep hole.

A slushy subsurface ocean might also explain the "chaos terrain," a region littered with fractured and rotated blocks of ice the size of several city blocks. The new images show rough, swirly material between the chunks — possibly slush that froze when it rose to the frigid surface.

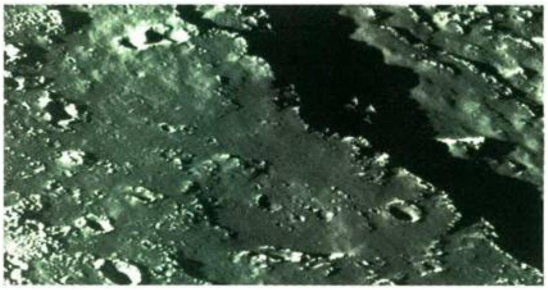
Finally, the latest images reveal that the darker wedge-shaped gaps found between large plates of ice show many similarities to new crust that forms at the mid-ocean ridges on Earth's seafloor. The best current guess is that the new crust welling up between the separating plates on Europa started as slushy ice or maybe even liquid water that froze and then fractured.

"Together, the evidence supports the hypothesis that in Europa's recent history, liquid or at least partially liquid water existed at shallow depths below the surface in several different places," says James Head of Brown University, a leader of the research team. However, the ultimate proof of a subsurface ocean will likely have to wait for a future mission, called Europa Orbiter. It is scheduled for launch in 2003, and will use radar that can penetrate the surface ice and detect an ocean, if one exists.

Eye on Io

If Europa is ice, Io is fire. Io's massive volcanic eruptions dwarf anything like them in the solar system. Its volcanic plumes spew hundreds of miles above the surface. Some of its hot spots boil above 1,000° F, an indication that Io remains the focal point of the gravitational tug-of-war in the jovian system.

Unfortunately, Galileo flew near Io only once — when the camera was turned off just before the spacecraft rounded Jupiter and entered into orbit. Yet Io remains the most studied of the moons because Galileo views it frequently from long range. The continuing observations have helped mission scientists monitor the moon's geologically active surface.



This prominent scarp forms a small part of the Valhalla multi-ring structure on Jupiter's battered moon Callisto. A huge impact early in the moon's history formed the 2,500-mile-wide Valhalla.

The most spectacular of these occurred at the volcano Pillan Patera between April and September 1997. During this interval the volcano erupted, creating a dark smudge the size of Arizona, about 250 miles (400 km) across. "This is the largest surface change on Io observed by Galileo during its entire two-year tour of the jovian system," says imaging team member Al McEwen of the University of Arizona.

Despite this and other eruptions on the moon, most of Io's hot spots seem to simmer quietly for long periods. Many of those observed by Galileo were also seen by the Voyager spacecraft nearly 20 years ago. (A few had been detected from the ground.) Most of the dozens of new hot spots seen for the first time with Galileo's more sensitive instruments have persisted from orbit to orbit.

The mission has not just looked at the surfaces of Jupiter's moons, however. In one of its more important findings, Galileo discovered that Ganymede, the largest moon in the solar system, possesses a magnetic field. It thus becomes the first moon known to possess an intrinsic magnetic field, although there are tantalizing hints that both Io and Europa may harbor such fields.

A Peek inside the Moons

Galileo also found that Io, Europa, and Ganymede have metallic cores while Callisto does not. During the flybys, scientists used the spacecraft as a probe of the gravitational fields of the moons. "Before Galileo, we could only make educated guesses about the structure of the jovian moons," says John Anderson, a planetary scientist at the Jet Propulsion Laboratory. "Now with the help of the spacecraft, we can determine their interior structure and density."

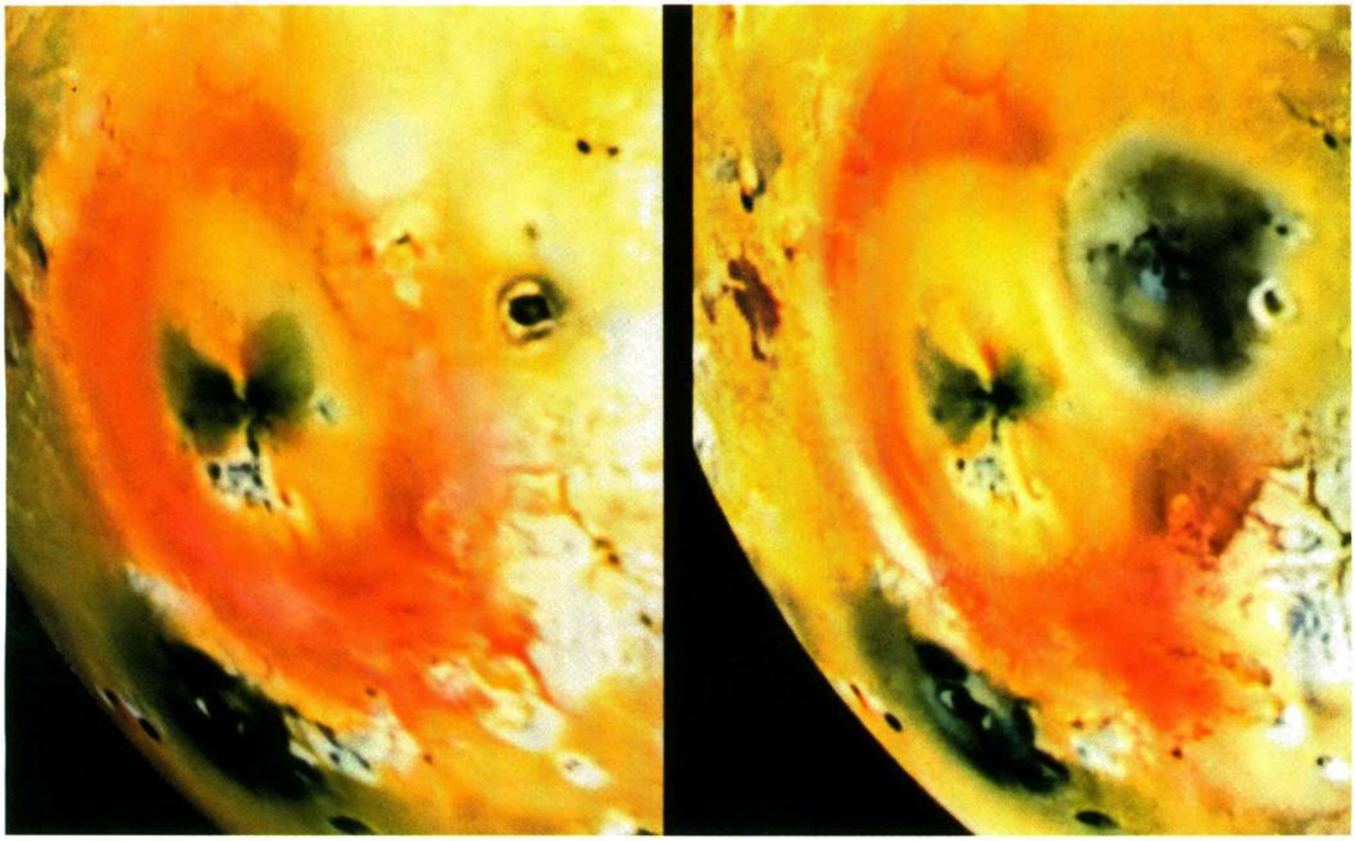
There's nothing unexpected about the three inner moons having cores. As the interior of an object becomes molten, lighter material naturally rises toward the surface while heavier material sinks to the center. (That's why Earth has a heavy core consisting of iron and nickel and a lighter crust made mostly of silicates.) But the lack of a core in Callisto has so far proved baffling. Although it lies too far from Jupiter to experience the tidal forces and subsequent heating the other moons feel, the heat generated during Callisto's formation should have lasted long enough for the material in its interior to separate.

Galileo investigators have also looked above the surfaces of the four Galilean satellites, and in each case they have discovered a very tenuous atmosphere. Callisto's atmosphere consists of hydrogen, oxygen, and carbon dioxide, while on Ganymede hydrogen seems to be the most prevalent gas. The hydrogen and oxygen apparently come from molecules of water ice that have been knocked off the surface either by solar radiation or highly energetic charged particles in Jupiter's magnetosphere.

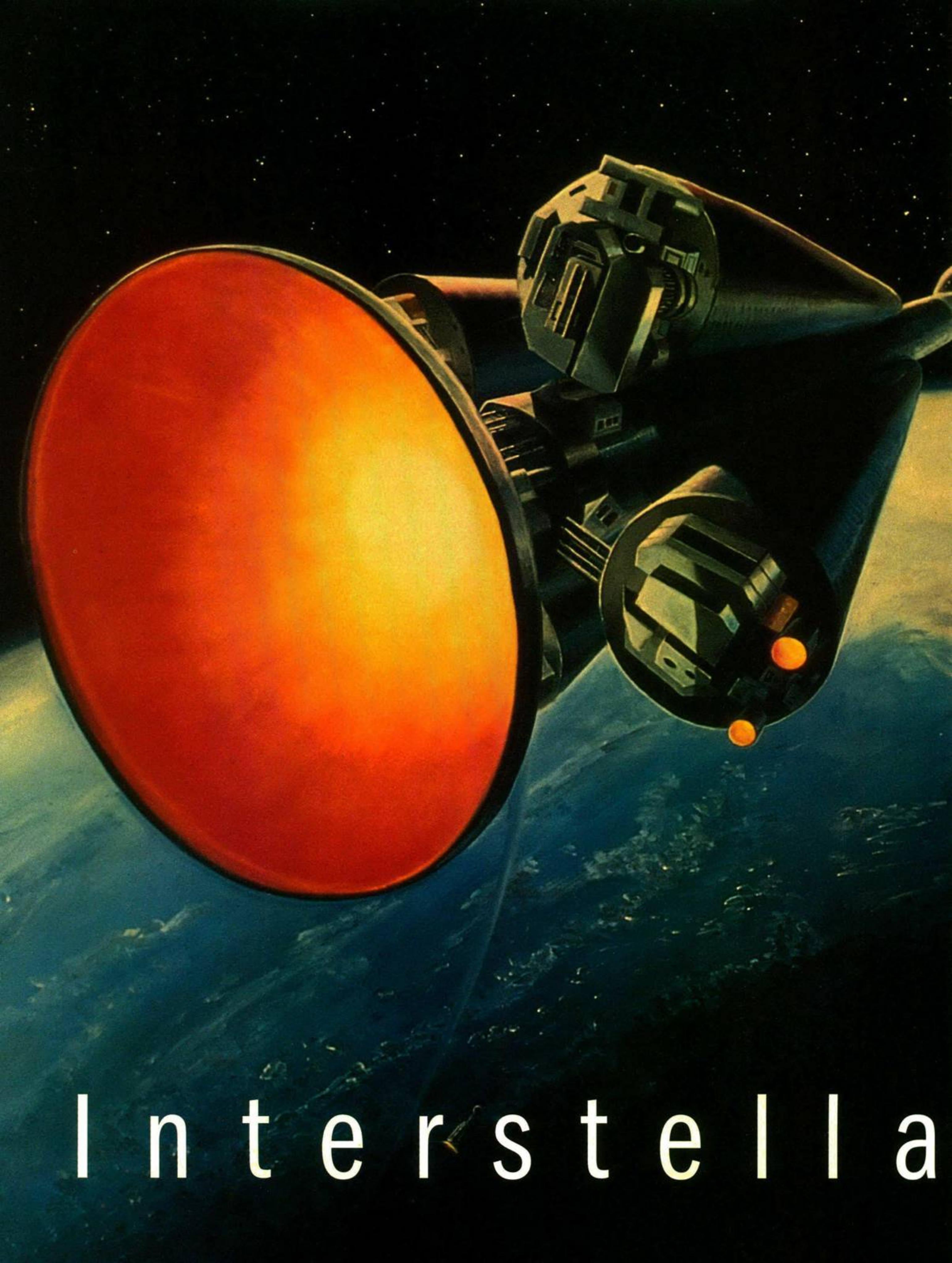
Oxygen seems to dominate the very thin atmosphere above Europa, and oxygen, sulfur, and sulfur dioxide mingle in Io's atmosphere, which result mainly from volcanic out-gassing.

The giant planet itself has come under its share of Galileo's scrutiny. Studies show that water circulates vertically in the upper reaches of the jovian atmosphere, leaving large areas drier than the Sahara Desert and others as moist as a tropical rain forest. Observations of huge thunderstorms, which can grow to heights several times those on Earth, confirm that the storms provide energy for the low-pressure regions on Jupiter, which in turn feed the Great Red Spot, white ovals, and other large storm systems.

Galileo's two years may have been remarkable. But the mission hasn't answered many questions scientists have about Jupiter and its moons. Expect the upcoming Galileo Europa Mission to continue the discoveries and to lay the groundwork for more sophisticated spacecraft in the next decade and beyond. ■



A massive eruption at Pillan Patera transformed Io in mid-1997. A dark spot the size of Arizona appears at the upper right of a September image (right), whereas none appeared in April (left). The red oval is ejecta from the volcano Pele.



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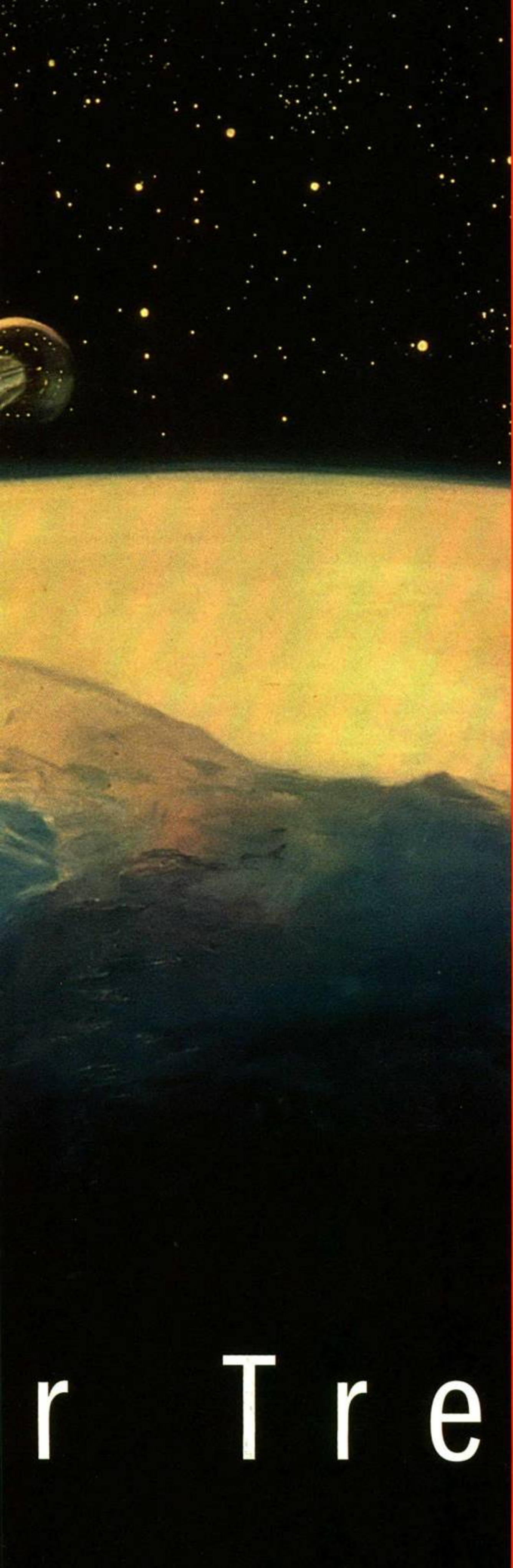

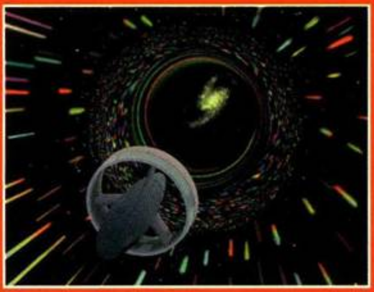

r Trekking

Will human beings ever travel to the stars? Don't pack your bags just yet....

by Ken Croswell

The stars — red, yellow, orange, blue, and white — shine from across voids of trillions of miles, far beyond the most distant planets of the solar system. At least some of these stars, astronomers now know, warm orbiting planets, and future years should see the discovery first of dozens and then of hundreds of new planets, some of which may harbor water and even life.

From afar, astronomers can try to study these planets and deduce basic properties, but the only

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Previous Spread (large painting): Humans may someday travel to the stars in spaceships like this one, but it won't happen anytime soon. (*Astronomy:* Thomas Schroeder) (Small photo): Artwork by Les Bossinas/ courtesy of NASA Lewis Research Center

way to scrutinize them in detail is by sending spacecraft. Before spacecraft flew past the sun's planets, astronomers knew little about them: Some thought Venus had oceans, Mars canals, and no one knew much at all about distant worlds such as Uranus and Neptune.

PROSPECTS AND PROBLEMS

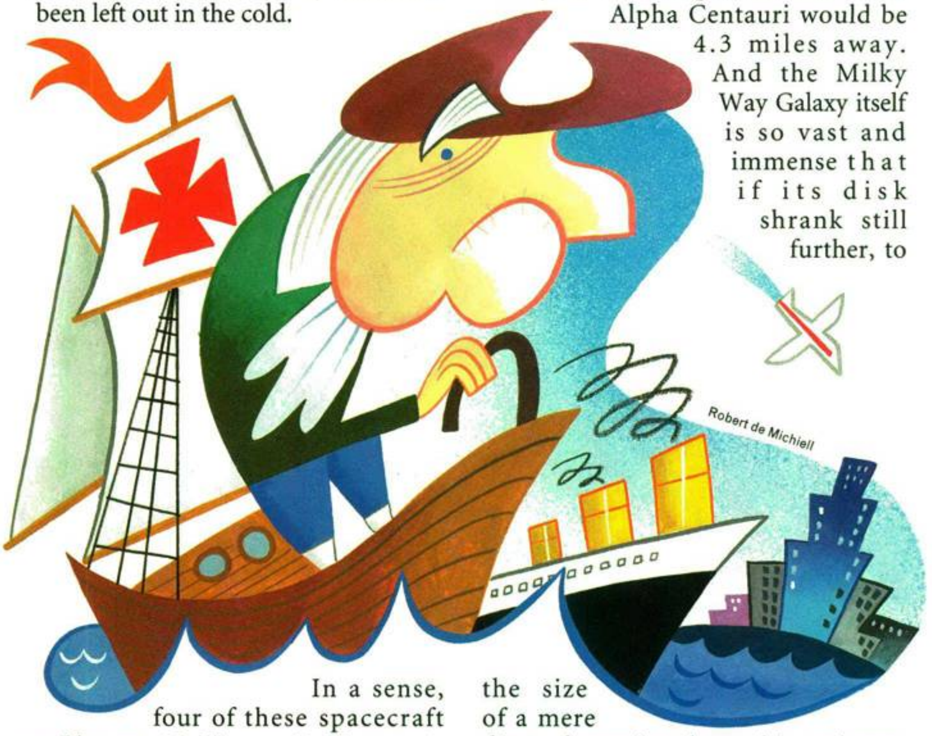
Despite the appeal of voyaging to the stars and seeing their planets close-up, some scientists believe such missions will never occur. In 1960, Harvard astronomer Edward Purcell wrote, "All this stuff about traveling around the universe . . . belongs back where it came from, on the cereal box." The energy and expense of a journey to Alpha Centauri — the closest star system to the sun — would be enormous, problems that even interstellar travel advocates concede. In 1996, longtime starship proponent Robert Forward wrote, "Interstellar flight is difficult and expensive, but not impossible."

Proponents like to point to amusing statements denying the possibility of things everyone now takes for granted. For example, early in the 20th century, some scientists claimed that airplanes would never fly across the Atlantic. But opponents of starflight can point with equal glee to past statements that have erred in the opposite extreme, such as predictions that people in the 1990s would commute to work in their own personal helicopters.

Some astronomers even have a vested interest in ridiculing interstellar travel. They believe, without any evidence, that intelligent life is common in the galaxy. Yet none of this life has ever visited Earth, a fact that prompted physicist Enrico Fermi in 1950 to ask the famous question, "Where are they?" To explain this apparent contradiction, now called the Fermi paradox, astronomers who believe that extraterrestrial intelligence exists argue that interstellar travel is so difficult and expensive that no civilization would undertake it. Thus, we Earthlings will never succeed at it, either.

Astronomy: John Clark

To date, humanity's spacecraft have explored all the sun's planets from Mercury to Neptune; only Pluto has been left out in the cold.



Robert de Michiell

In a sense, four of these spacecraft — Pioneer 10, Pioneer 11, Voyager 1, and Voyager 2 — are humankind's first interstellar craft, because all are now leaving the solar system at high speed, bound for the stars (see "Voyager 1 is Far Out!" page 28). The Pioneer spacecraft cover about 2.3 times the distance between the Earth and sun every year, and the faster Voyagers, about 3.4 Earth-sun distances per year. But the stars are so distant that even the Voyager spacecraft would require 80,000 years to reach Alpha Centauri, about 4.3 light-years away, if they were heading in that direction. With luck, however, they will never make it that far: Spacefarers of future centuries will overtake and capture those spacecraft and preserve them in a space museum.

DISTANT DESTINATIONS

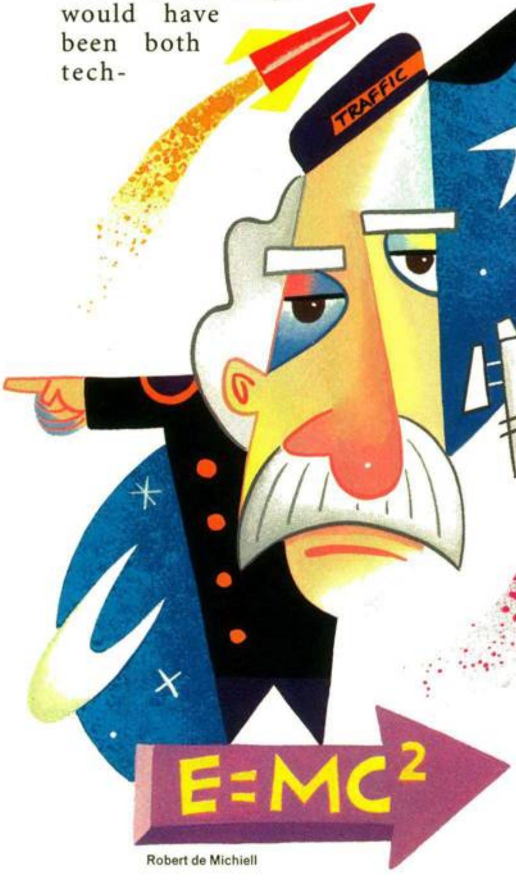
The greatest difficulty confronting voyagers to the stars stems from the stars' enormous distances. Astronomy enthusiasts toss around distances in light-years so often that they sometimes forget just how incredibly large a light-year is. Light is swift: In a single second, a light beam could whip around Earth 7.5 times, so the distance that light travels in an entire year is gargantuan. Imagine that the galaxy shrank so much that Earth and the sun were an inch apart. Then Jupiter would be just five inches from the sun and distant Neptune only 30 inches. On this same scale, though, a light-year would equal a full mile, so Alpha Centauri would be 4.3 miles away. And the Milky Way Galaxy itself is so vast and immense that if its disk shrank still further, to the size of a mere dime, the entire observable universe, from Earth to the farthest known quasar, would be only two miles wide. We live in an enormous galaxy whose stars are separated by enormous distances.

To cross those distances, starships must travel fast. The Voyager spacecraft move at 0.005 percent of the speed of light, but a true starship must attain at least 10 percent of the speed of light in order to reach Alpha Centauri in less than half a century, so that at least some of the scientists who plan the mission are still alive when the spacecraft reaches its destination. By contrast, a ship that left the solar system with "only" one percent of light speed would require 430 years to get to Alpha Centauri, and during that lengthy time technological improvements on Earth might have enabled the construction of faster starships. Imagine if a long-lived Christopher Columbus had taken 500 years to sail the Atlantic. He would have watched faster ships pass him by, and then airplanes zipping between Europe and America, all before he ever reached America. When he finally got there, the New World would have looked *really* new to Columbus, but pretty old to everyone else.

Traveling a significant fraction of the speed of light, however, is difficult, because it costs great amounts of energy — and money — to attain high speeds. For example, a one-ton ship traveling at a third the speed of light would use as much energy as the United States consumes in three weeks. By solar standards, however, this is not much, since every second the sun radiates into space millions of times more energy. So the energy is there, if human beings can figure out how to harness it.

The cost of such a mission might be more than a trillion dollars, another impediment that critics cite. But a trillion dollars is loose change compared with what the American gross domestic product will be in future centuries. If the American economy grows at the modest rate of two percent per year after inflation, then in two centuries the GDP will be 52 times larger than it is now, or about $350 trillion in current dollars. What is outrageously expensive today may be cheap centuries hence. After all, a moon flight would have been both technically impossible and ridiculously expensive to the American colonists in 1776, yet their descendants successfully put a man on the moon less than two centuries later. And if we can put a man on the moon using 1960s technology, why can't our descendants put one in orbit around Alpha Centauri?

Undoubtedly, the first interstellar voyages will carry only machines, not people. Human beings have reached no farther than the moon, whereas robotic spacecraft have already made it past Neptune. Human beings require air, water, food, and a modicum of comfort; machines do not. Furthermore, in coming decades, computers and other instruments will become smaller, lighter, and more powerful, thereby reducing the weight that a spacecraft must carry.



Robert de Michiell

EINSTEIN'S CURSE

An interstellar voyage must confront Einstein's special theory of relativity, which describes the effects on objects that travel at an appreciable fraction of the speed of light. The best-known relativistic barrier is the speed of light itself, which ensures that Earth's residents will always have to wait at least 4.3 years for a ship to get to Alpha Centauri and then another 4.3 years for the ship's data to reach Earth.

Special relativity also affects mass and time. As a ship's speed increases, so does its mass, which is bad because it makes it harder to accelerate the spaceship to still greater speeds. But to any passengers aboard the ship, time proceeds more slowly, which is good because they can travel even farther. These two relativistic effects, involving mass and time, are small at low speeds and grow greatly as a ship nears the speed of light. At the speed of light, the mass becomes infinite, which is why no material body can actually travel that fast.

To gauge the severity of these relativistic effects, scientists employ the Lorentz factor, named for Dutch physicist Hendrik Lorentz. The Lorentz factor depends on speed: It is exactly one at zero velocity and increases at higher ones, becoming infinite at the speed of light. At 20 percent of the speed of light, the Lorentz factor is only 1.02, which means that a starship this fast is only two percent more massive than it was at rest, and time slows so that the crew sees one hour elapse in the time that 1.02 hours pass on Earth. At 50 percent of the speed of light, the Lorentz factor is 1.15, which is still fairly low: The mass is now 15 percent greater than it was at rest, and one ship-hour equals 1.15 hours on Earth. Only at speeds over 80 percent of the speed of light does the Lorentz factor start to rise greatly. It reaches 2.00 at 87 percent of light speed, which means that mass doubles and time halves.

As a ship's speed increases, so does its mass, which is bad because it makes it harder to accelerate the ship to still greater speeds.

LIFE IN THE FAST LANE

The real problem for proponents of interstellar travel is not special relativity but how to attain the high speeds at which it becomes a concern. Even 10 percent of the speed of light — 67 million miles per hour — vastly exceeds the fastest spacecraft ever launched.

In principle, the best rocket fuel is the one Captain Kirk uses: antimatter, which mirrors ordinary matter. In ordinary matter, the atomic nucleus is positively charged and the orbiting electrons are negatively charged. But in antimatter, the atomic nucleus is negatively charged and the orbiting "electrons," called positrons, are positively charged. When matter meets antimatter, they completely annihilate each other, converting all mass into energy. Matter and antimatter are therefore potent fuels, because even a small amount of mass, m, contains an energy E equal to mc^2. Since c, the speed of light, is so large, multiplying the speed of light times itself means the amount of energy in even a small piece of matter, or antimatter, is huge. If you shook hands with your antimatter twin, the resulting energy could power the entire United States for the next two months — or send a small interstellar spaceship to Alpha Centauri.

Unfortunately, antimatter does not exist naturally on Earth, and astronomers know of no sources of antimatter in the solar system. Antimatter does arise in nuclear reactions, but only in minuscule quantities, and to produce even the relatively small amount of antimatter needed to power a starship would be extremely expensive: Antimatter presently would cost trillions of dollars per *ounce*, even if scientists could find a way to contain it.

Any rocket, even one powered by a matter-antimatter drive, suffers a basic curse: It must accelerate not only the spacecraft but also the fuel itself. Thus, the rocket must carry more fuel just to accelerate that fuel, but the more fuel the rocket carries, the more additional fuel it must carry to accelerate that extra fuel — it's a Catch-22 situation. Scientists have therefore devised schemes to accelerate starships without rockets. In 1960, Robert Bussard suggested using the fuel in space itself.

Particles that exceed the speed of light are called tachyons, but no one has ever seen one.

Seemingly empty space contains a trace of hydrogen atoms. If a starship could scoop these up and fuse them together in a nuclear reactor, the resulting energy could power the ship. Unfortunately, interstellar space contains only about one atom per cubic centimeter, so the ship would have to scoop up atoms over a radius of hundreds or thousands of miles.

Another scheme that gets rid of the rocket has been advocated by Robert Forward, who proposes that lasers push ships through space. This works because light itself exerts pressure. Since this pressure is weak, the lasers must be large and powerful, covering hundreds of miles, and their beam must remain collimated over trillions of miles of space. If the spacecraft carries people, they would have little control over their voyage. Instead, they would be at the mercy of the laser station, light-years behind them.

FASTER THAN LIGHT?

Such ideas may sound far-fetched and suggest that starflight is indeed as impractical as its critics allege, but at least these proposals employ known physics. Even more speculative schemes invoke new and unproved physics. For example, shortcuts called wormholes might exist in space that would allow spaceships to travel from the sun to Alpha Centauri without passing through the entire 4.3 light-years of space between the two. It would be like tunneling through Earth from the United States to China instead of treading the longer route over Earth's surface.

Also in the domain of speculation is faster-than-light travel. Technically, Einstein's special theory of relativity does not rule this out. At the speed of light, the Lorentz factor is infinite, but above this speed, it becomes what mathematicians call imaginary (such as the square root of a negative number) and actually decreases as the ship's speed increases. How one could cross the light-speed barrier, at which the Lorentz factor becomes infinite, is unclear, and jumping back from faster-than-light speed to slower-than-light speed may be downright impossible. Particles that exceed the speed of light are called tachyons, but no one has ever seen one, which suggests that even nature itself does not know how to make them. Perhaps a parallel universe exists in which everything is forced to travel faster than light, and people there long to lead a slower life. Maybe we can make a deal with them.

This artist conception shows a group of interstellar spaceships bound for the solar-type star Tau Ceti, 11 light-years away. The technology to accomplish this mission lies centuries in the future. *Astronomy*: John Clark

Until we hear from such a universe, scientists must struggle with the one they know. As a first step toward actual interstellar travel, scientists have proposed launching a robotic mission that would travel fast and far enough to test some of the concepts of interstellar flight without actually reaching the nearest stars. The proposed craft is named TAU, because it would conduct science a thousand astronomical units from the sun, or 25 times the mean distance of Pluto. The ship would take about a century to achieve that distance, which is only a fraction of one percent of the distance to Alpha Centauri. Still, the TAU spacecraft could

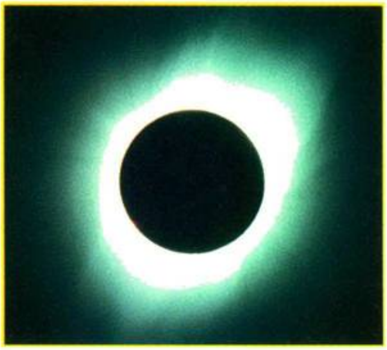
serve as a trailblazer for faster craft.

The challenges of interstellar travel are enormous — perhaps so enormous that its critics are right, and no civilization will ever be able to achieve it, thereby explaining why our galaxy could abound with intelligent species we have never met. Yet it would be folly to dismiss the capability of terrestrial civilization a few centuries from now, let alone those of other civilizations that may be millions or perhaps even billions of years more advanced. Furthermore, if a genuine twin of Earth were discovered around a nearby star such as Alpha Centauri, Lalande 21185, Epsilon Eridani, or Tau Ceti, an event that could occur in the next two decades, the urge to explore that world directly with spacecraft would be irresistible. Conceivably, such a mission could be launched during the 21st or 22nd century. If so, those who believe that intelligent life is common in the cosmos would be forced to explain why none of that life has done the same and launched a mission toward one of the galaxy's most promising star systems: the sun. ■

To learn more about interstellar travel, check out the following NASA web site: http://www.lerc.nasa.gov/WWW/PAO/ warp.htm.

Ken Croswell is an astronomer in Berkeley, California, and author of two critically acclaimed books, The Alchemy of the Heavens *and* Planet Quest. *The home page for both books is http://www.ccnet.com/~galaxy.*

Magic in the MOO



Astronomy's *eclipse expedition provided eager skywatchers with a spectacular view of the moon's shadow.*

by David J. Eicher

AT 12:30 P.M. ON FEBRUARY 26, THE SHIP SLID through the water at 20 knots and warm Caribbean rain began to fall. Many of the 1,800 passengers and 900 crew members onboard the *Galaxy*, Celebrity Cruise Lines' newest ship, ran for cover below deck; a few shrieked in panic. The moon would take its initial bite out of the sun in 35 minutes; totality would begin in two hours. Rain? This must be a bad dream.

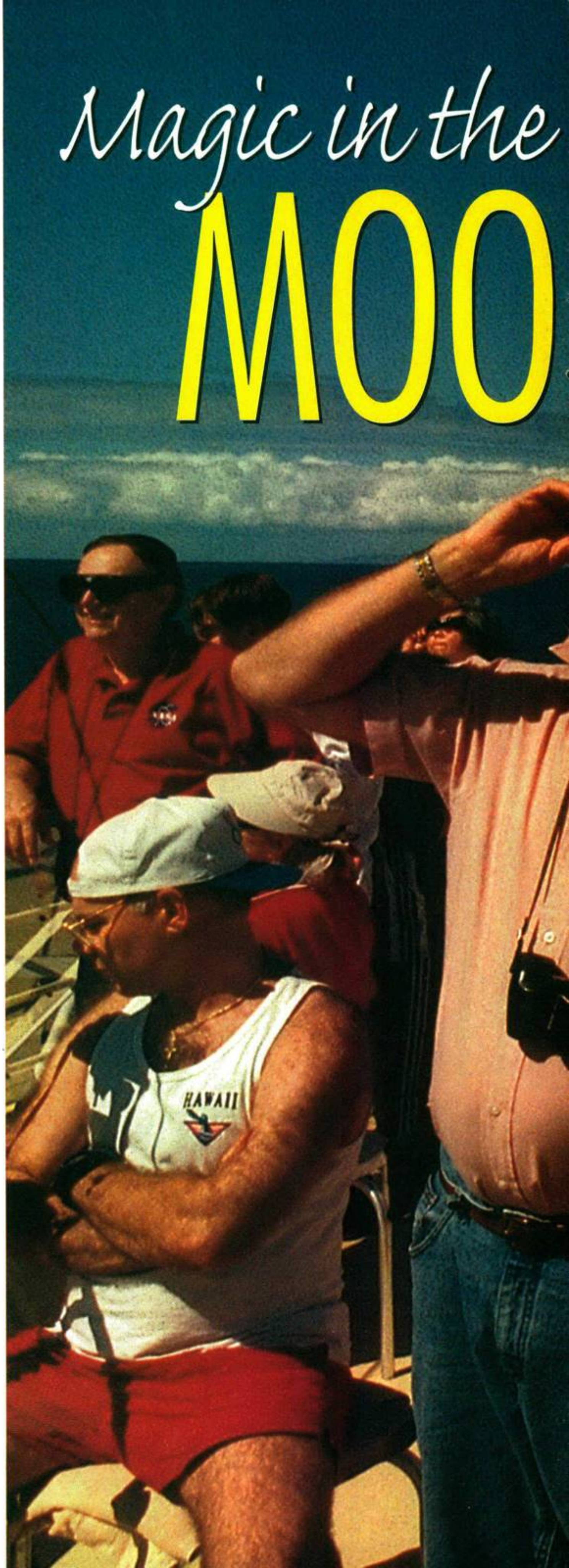
The officers on *Galaxy's* bridge had detailed radar and satellite imagery and knew exactly where they were going. It was to a spot smack on the centerline south-southwest of Antigua and northwest of Guadeloupe, where only clear blue skies prevailed. As the ship moved forward and the sky opened up, cheers went up — and well before first contact.

The journey to last February's solar eclipse would be attended by another demonstration of nature's power. For nearly an hour, the ship plied past Montserrat, offering a clear view of the active Soufriere Hills volcano that has devastated the island, spilling ash-covered lava flows over 30 percent of the eastern slopes.

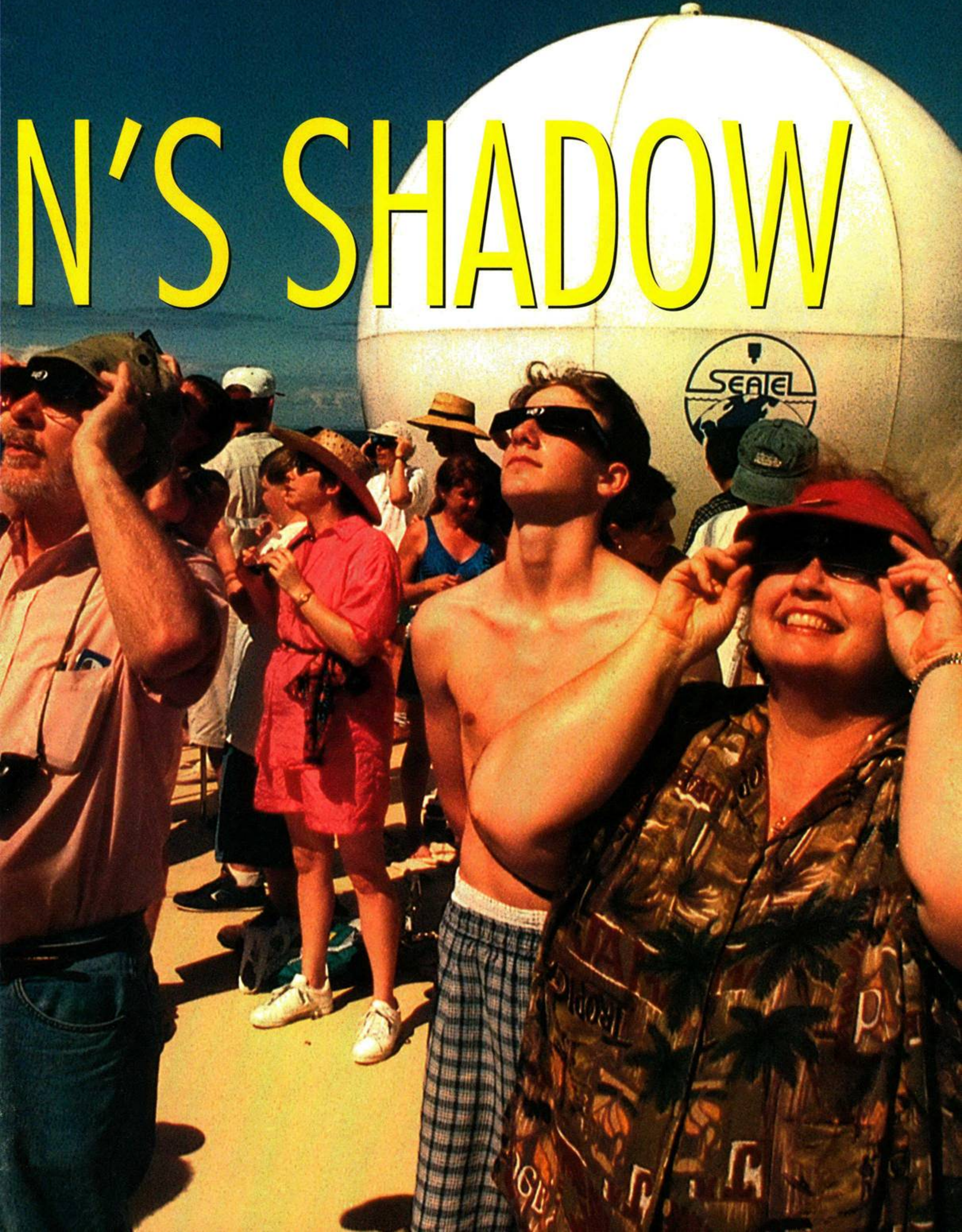
As spectacular as the sight was, it was a sideshow to the day's main event. At 1:05 p.m. local time, members of *Astronomy*'s eclipse group, some 430 strong, watched first contact. Many of us stood on deck near the bow. Others chose to watch from lower decks that stretched beside the pool. Half the magazine's editorial staff was witness to this eclipse. We gazed through our aluminized mylar glasses as the tiny nick taken out of the sun's disk grew. Cruisers who had lugged equipment to San Juan, the embarkation point, moved their scopes and cameras into position and counteracted as best they could the slight roll of the ship's deck.

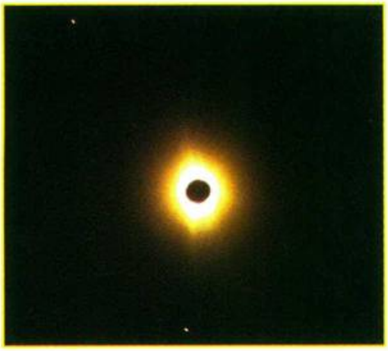
The minutes ticked by, but the real action had not yet begun. Some, beset by nerves and the need for carbohydrates, went below and returned with food to squeeze in lunch before totality. At 1:45 p.m. the ship's engines stopped.

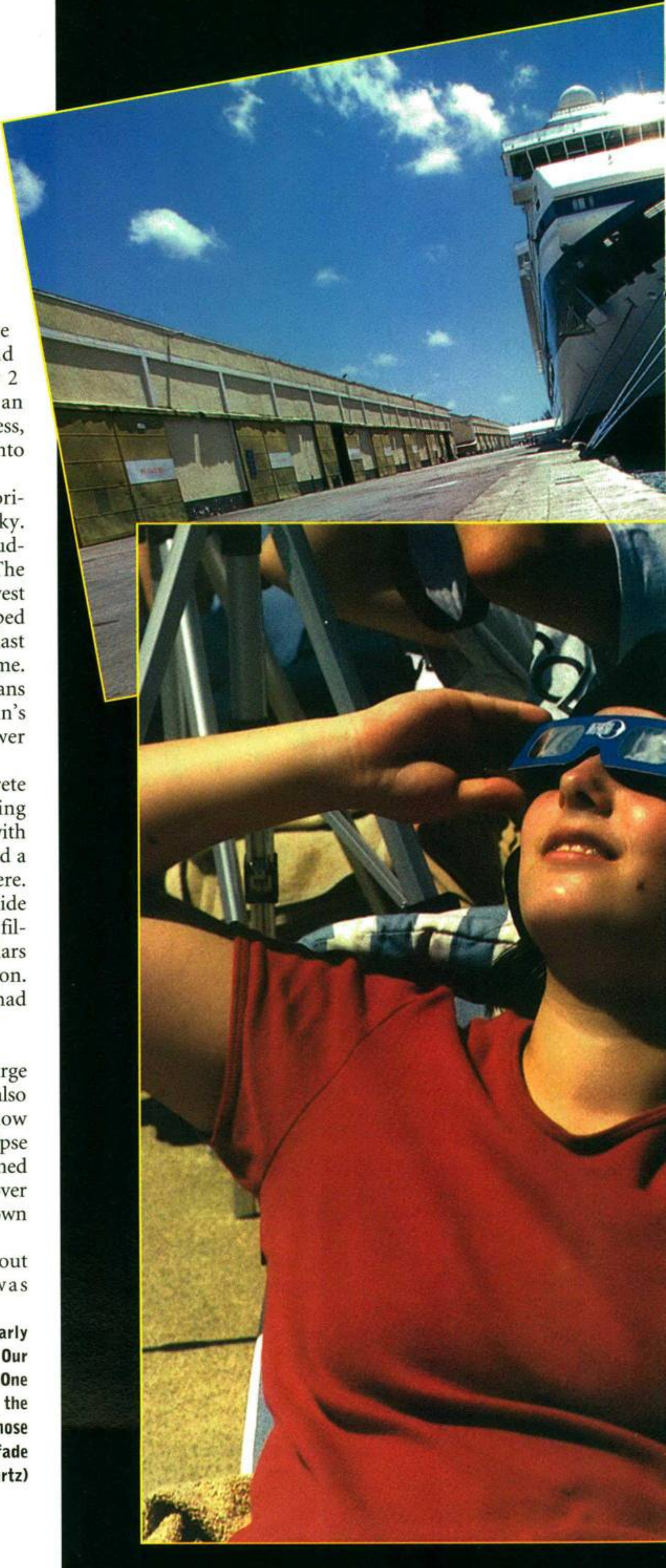
Coronal streamers are captured at totality, above. (Dan Koehler)
Eclipse gazers watch for a complete shadow. (Raleigh Souther)



N'S SHADOW







Montserrat's volcano was now at our backs, Guadeloupe was ahead in the distance, and another cruise ship and perhaps two dozen smaller craft sailed the horizon. By 2 p.m. the eclipse began in earnest; the sky darkened to an ethereal light. Shadows took on their characteristic sharpness, and people projected pinhole images of the crescent sun onto the deck using cards and even straw hats.

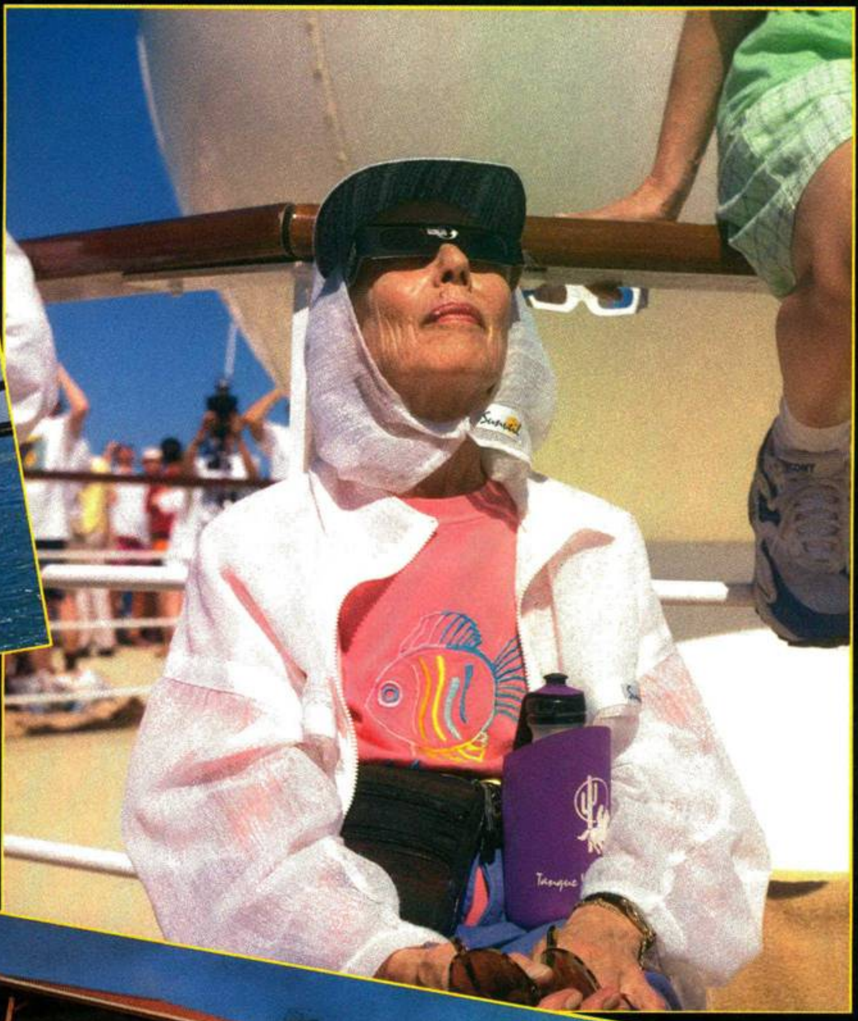
Before we knew it, pseudo-twilight began to ring the horizon, and brilliant Venus popped into the southwest sky. Now events seemed to accelerate toward the big show. Suddenly there were five minutes, then, two minutes, left. The moon's shadow appeared prominently toward the southwest and came like a wall across the water. The sun's light slipped away quickly, the initial diamond ring flashed, and the last gasp of sunlight became a brilliant corona at 2:31 local time. The sharpness and detail in the coronal streamers and fans gave the sun a flowery shape. On the top edge of the sun's disk, a huge finger-shaped prominence appeared to tower upward. Jupiter and Mercury came out in the dark sky.

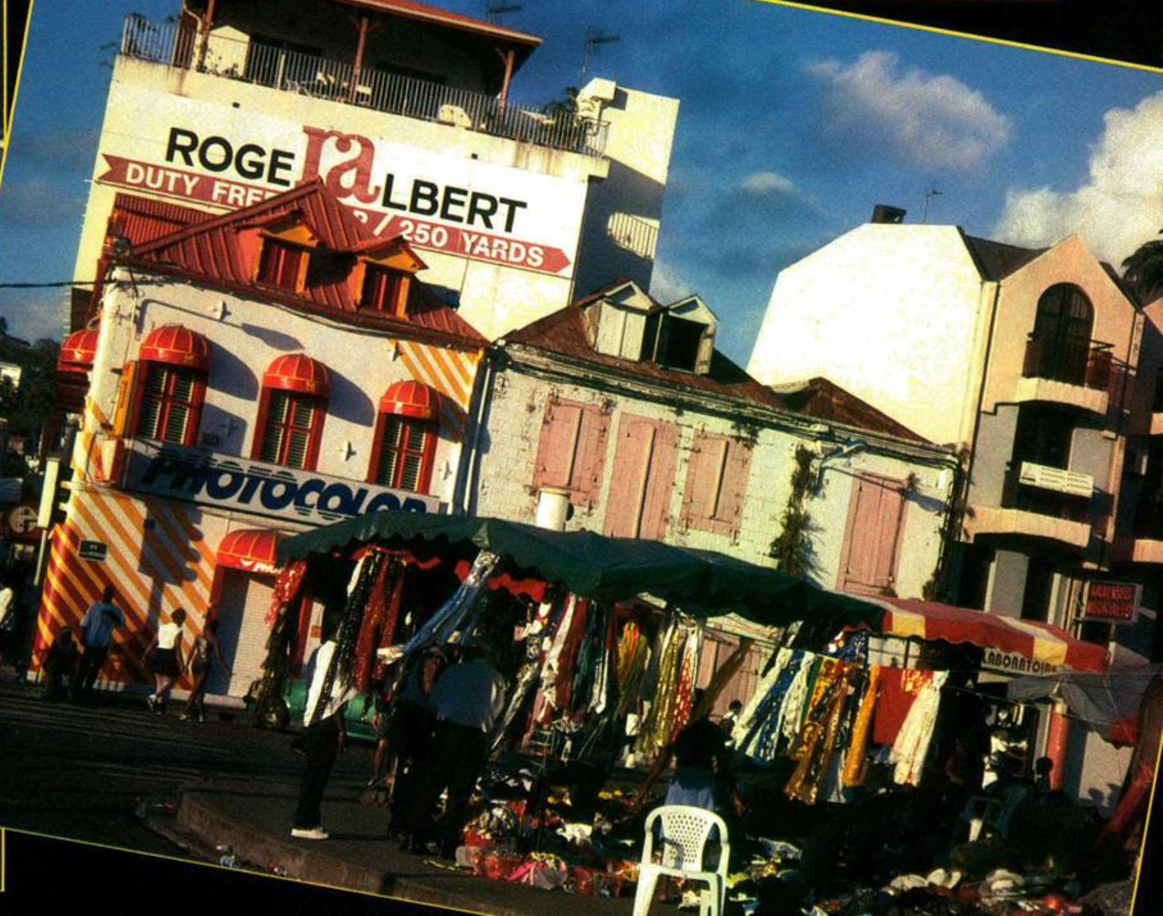
The emotional energy of eclipse chasing set like concrete during those seconds of totality. Photographs were being snapped, people were simply stepping back and looking with the naked eye, a few quick passes of the binoculars ensured a close-up peek of the corona, and delight reigned everywhere. And then came the diamond ring again, on the opposite side of the sun. Screams all across deck warned viewers to use filters once again and Baily's beads appeared, signaling pillars of sunlight flooding through valleys on the edge of the moon. Before we knew it, the fastest 3½ minutes of our lives had passed into history.

The big event was now a memory. The emotional charge one gets out of seeing such a display left all of us high and also tired. One of the oddest phenomena of eclipse chasing now played itself out. Despite that another 76 minutes of eclipse was left — the other side of the partial phases — few seemed interested in looking at the sun any further. The show was over and had been a grand success. Everyone could now sit down and relax on deck and recall pleasures of the previous week.

Astronomy's eclipse expedition, which accounted for about a quarter of the passengers aboard *Galaxy*, was

Mercury (rarely seen so bright) and Jupiter stood out against a nearly sunless sky, above. (Michael Oblath) Clockwise from top left: Our cruise ship *Galaxy* rests in Barbados's harbor. (Fred Vroom) One transfixed cruiser awaits totality. (Peter Sutter) Vendors enliven the streets of Martinique. (Peter Sutter) Kimberly Dunn, whose 13th birthday occurred on the day of the eclipse, watches the sun fade through mylar glasses. (Patricia Kurtz)




ROGER ALBERT
DUTY FREE
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Le 26 Février 98 à la Martinique
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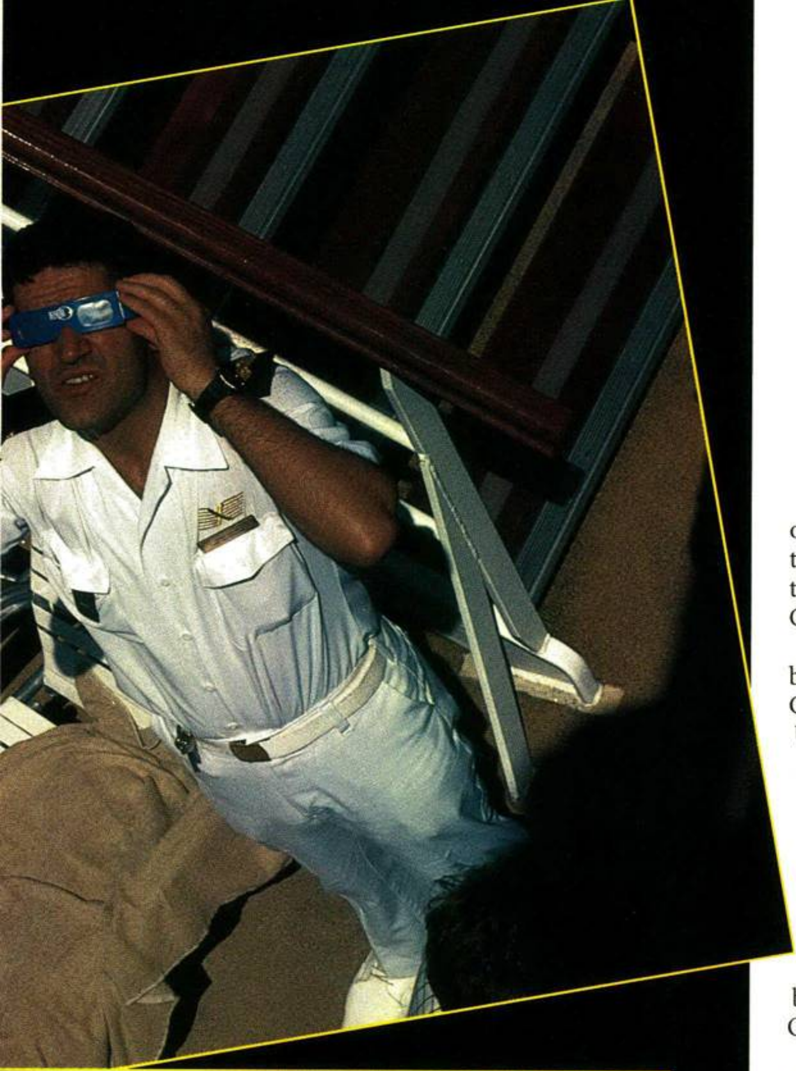
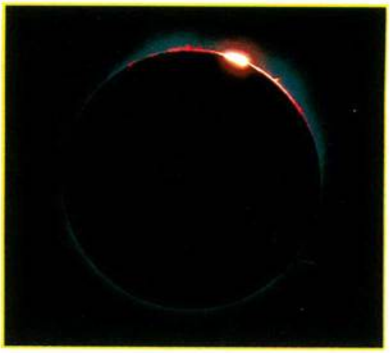


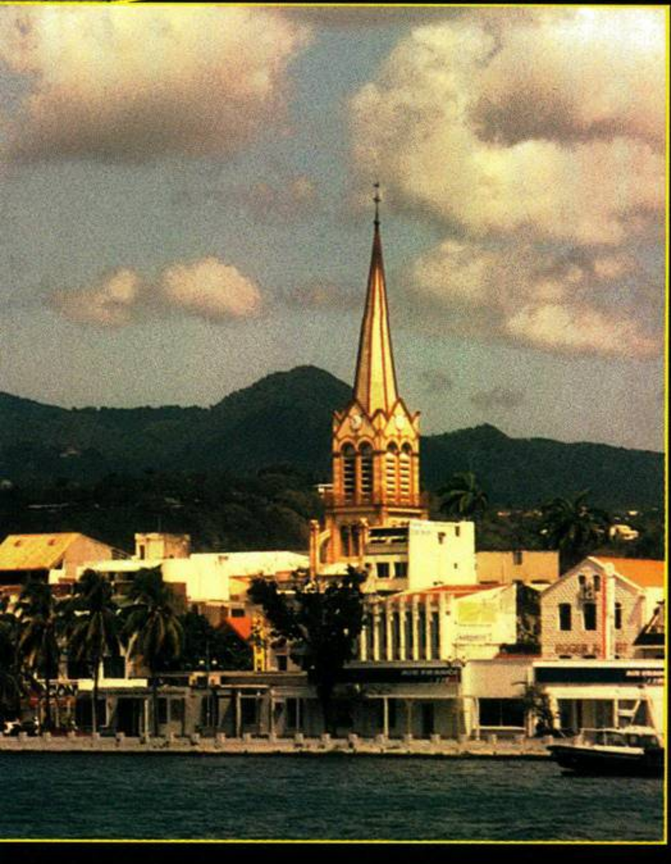


organized $1^{1}/_{2}$ years earlier. The itinerary allowed us to enjoy the eclipse, a fine voyage, and a variety of special events, talks, and shore excursions on Puerto Rico and five smaller Caribbean islands.

On the first Friday evening of the trip, for example, tour buses transported *Astronomy's* eclipse chasers from the Caribe Hilton in San Juan to a reception and star party at the University of Puerto Rico at Humacao. The battery of telescopes set up on the rooftop of the physics and astronomy building offered guests some of their first views of the southern Milky Way, although the night was intermittently cloudy. We would have universal success a few nights later when the ship turned out all save the running and emergency lights, and we saw the Southern Cross, the Coal Sack, Alpha and Beta Centauri, the Eta Carinae Nebula, and Omega Centauri. On Saturday morning before embarkation, buses transported our group to Arecibo Observatory to see the world's largest radio telescope.

And though the eclipse, the related astronomical activities, and the luxury of the ship (with its nearly omnipresent French cuisine) stayed central in people's thoughts, the activities throughout the Caribbean added luster to the experience. Some of us golfed at Casa de Campo, Oscar de la Renta's resort in the Dominican Republic, where we were able to play the same oceanside greens as professionals. Others climbed onboard Atlantis, a recreational submarine that dove nearly 150 feet among reefs in Barbados and on St. Thomas. Still others snorkeled amid underwater caves in Martinique or swam with turtles.

The editors and our new friends, exhausted and bathed in sun, returned on February 28, just in time to piece together this report on our experience. We offer a selection of early reader photos of the eclipse as seen from our expedition in this month's Hot Shots (see p. 121). Next month, we'll bring you comprehensive coverage of the eclipse and another selection of reader photos. And for those who can't get enough of eclipses, we remind you that *Astronomy*'s 1999 eclipse excursions to England, Germany, and the Greek Isles are little more than a year away.



Light passing through the moon's valleys just before totality presents itself to us as tiny baubles called Bailey's beads, above. (Dan Koehler) Clockwise from top left: Guests enjoyed a trip to the radio telescope at Arecibo, Puerto Rico, before the cruise began. (Patricia Kurtz) Galaxy crew member sneaks a peek at the eclipse. (Peter Sutter) In Fort-de-France, Martinique, carnival ended the day before the eclipse. (Peter Sutter) Martinique vendor sells eclipse glasses during carnival. (Dennis Stark)

Mastering the MYSTERIOUS

From gamma-ray bursts to gravitational microlensing, Bohdan Paczynski has helped solve some of astronomy's great mysteries.

by Bob Berman

BOHDAN PACZYNSKI LOVES THINGS THAT wink on and off like holiday lights. It's a simple obsession that has led him, step by step and decade by decade, to the edges of the universe. Along the way it's made him one of the most respected voices in astrophysics.

Emerging to the forefront of not one, but two hot and apparently bizarre astrophysical problems, Paczynski (Pa-chin´ski) proved to be not merely ahead of the times — he also happened to be right.

"I always considered myself a theoretician even though I began as an observer, in a way," says Paczynski. That modest "in a way" refers to his study of variable stars while still an amateur, attending high school in Warsaw, Poland. Those observations formed the basis of his first scientific paper (a list of timings for a dozen or so eclipsing binaries) published in 1958. "But," he explains, "I did mostly theoretical work while an undergraduate at Warsaw University," publishing papers relating to galactic structure. It was an impressive level of braininess for an undergraduate and earned him an invitation to become a research assistant at Lick Observatory in California.

When I first met Paczynski, an impeccably polite man, he came across as somewhat reserved but soon relaxed into a friendly interchange. Warming to his subject, he became more animated with each recollection, revealing a playful wit which extended even to his view of peers who disagree with him.

Remembering his 14 months at Lick (the first of many early visits to the United States, which included stints at the University of Colorado, Caltech, and eventually a professorship at Princeton), he related incidents suggesting a charmed life.

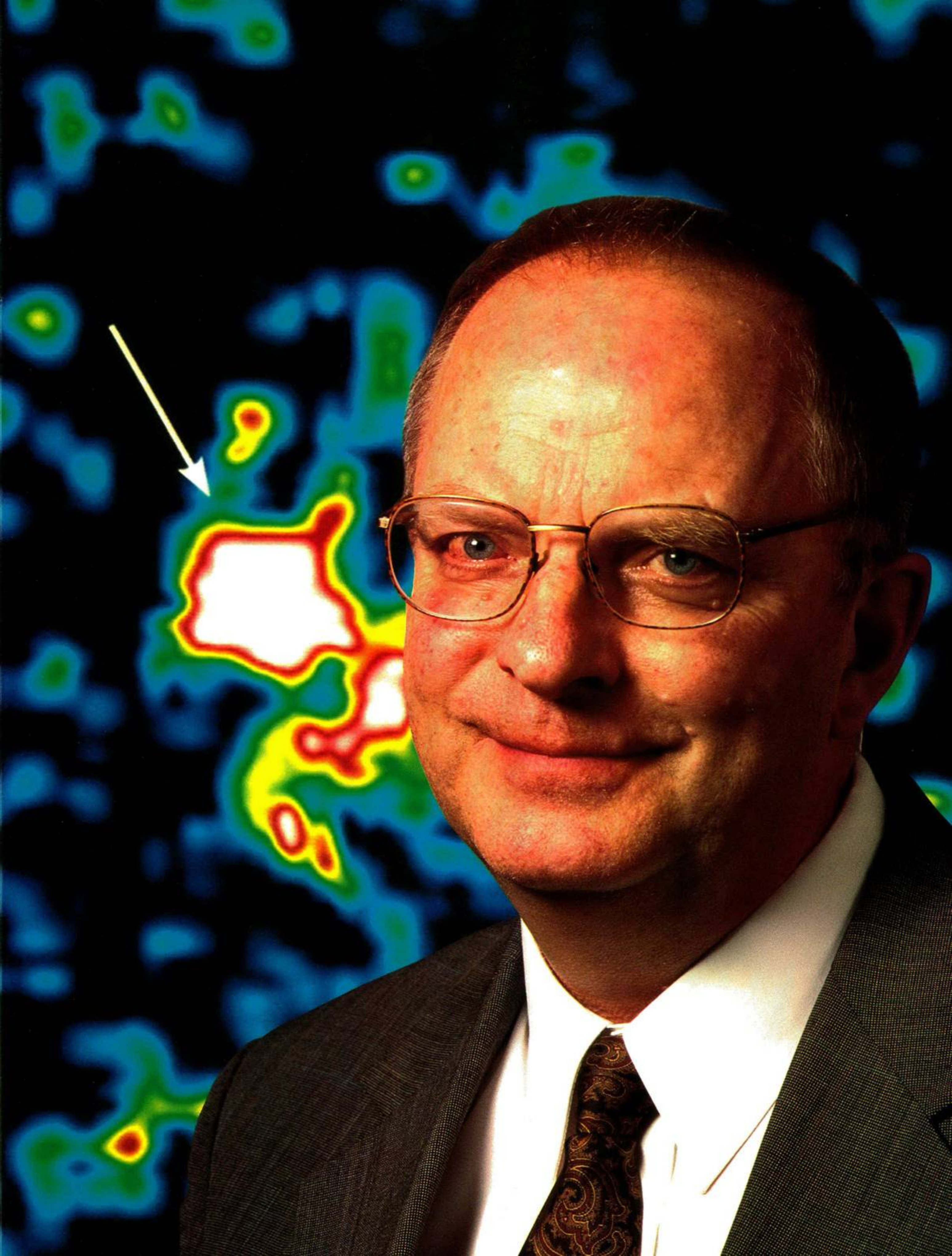
"I dozed off one night," he laughs, "and fell off the observing platform. But no harm done — other than a ten-minute gap in my observing program."

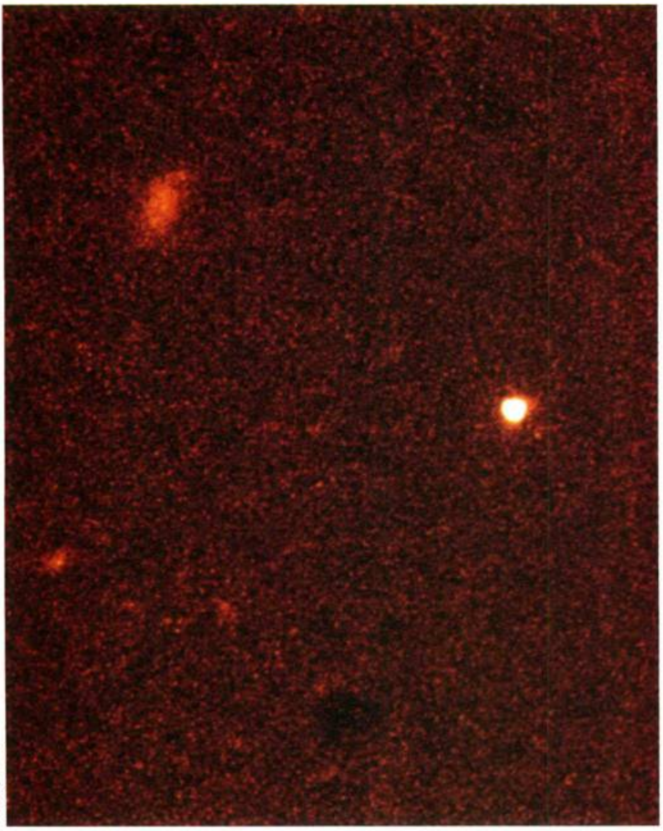
During those months when he lived in a dorm at the top of Mount Hamilton overlooking the San Francisco Bay area, he bought his first car and learned to drive on the tortuous road up the mountain. "It has 700 turns along just 24 miles," he recalls, "and I was told that a driver can make just one mistake. They showed me car wreckage down the canyons to prove it." But in this case, as in theoretical astronomy, Paczynski proved the experts wrong.

Barely. Although he once went off the road, he lived to publish a half-dozen papers derived from his Lick visit. His survival involved more than simple luck; he attributes it to the very low suspension of that era's American cars: "Two wheels went off the road and hung suspended out in the air over the canyon, while the car's bottom caught at the road's edge."

Meanwhile, Poland's Communist government considered astronomy harmless enough and Paczynski was allowed a passport and U.S. visitor's visa "most of the time." But not always. Years later he learned why he had occasional visa problems. It seems his "native city" statement on his visa application couldn't keep pace with the town's constant change of national affiliation: Wilno, Polish when he was born, was taken over by the Soviets, then became Lithuanian, German, and Soviet again. Now it's back under Lithuanian sovereignty (with the name Vilnius).

Paczynski sits before an HST image of the afterglow from the February 28, 1997, gamma-ray burst, which helped show that bursts lie in the far universe. Jon Goel (Paczynski) and NASA/STScI





NASA/STScI

The May 8, 1997, gamma-ray burst seen at the right of center was so bright that it could be seen from some eight billion light-years away.

Happily, he overcame the State Department obstacles and regularly joined colleagues on this side of the Atlantic.

If you were to watch Paczynski check his e-mail from his cluttered Princeton office, meet with faculty over morning coffee, or type intricate formulas clickety clack with two fingers stabbing the keyboard like woodpeckers, you might wonder where the leap occurs. At what point does that mysterious illuminating *something* allow the most brilliant among us to vault across the chasm that connects the human mind with the soul of space-time?

A COSMIC MYSTERY

Back in the 1980s, when orbiting satellites had already been telling us for nearly 20 years that bursts of the highest type of energy — gamma rays — occasionally popped in some part of the sky, it was anybody's guess what they were and how they were produced. Like flashbulbs igniting at random in a crowded stadium, these gamma-ray bursts lasted from a few thousandths of a second to several minutes. One even persisted for about the length of a feature film. These bursts were new stuff, a phenomenon never before seen.

There were two ways to look at these bizarre events. The first (which virtually everyone thought at the time) was that they lay within a few hundred light-years: The bursts arose in the Milky Way Galaxy. Maybe they were fireworks produced when a comet smashed into a neutron star or a "starquake" wracked a neutron star's surface. Later most astrophysicists pushed them a bit farther out — to the vast halo of invisible material in which the galaxy sits like a ship in a bottle. Placing the bursts fairly nearby meant the energy released was merely astoundingly high instead of off-the-chart.

"A theorist is allowed to intr

Paczynski instead argued that their distribution on the sky provided the critical clue to their distance. If the bursters were objects in our galaxy, he pointed out, we'd find them scattered primarily along the Milky Way, peppered amidst the band that rings our sky like a glowing highway. If, instead, they were part of the galaxy's halo, they still wouldn't show a uniform distribution since Earth is not centered in this city of suns. Because our planet's little plot of celestial real estate sits in a spiral arm some 26,000 light-years from Galactic Downtown, the distribution of bursts should follow the pattern of other halo objects such as globular clusters — that is, skewed in one direction. But this, too, isn't the case. Instead, bursts exhibit a perfectly random and uniform distribution (see map on opposite page). And unless you accept what Paczynski saw as implausible rationalizations, this means they faithfully follow the configuration of faraway galaxy clusters and therefore lurk at cosmological distances. Anything else made him squirm. "As astrophysicist David Schramm put it," he says, leaning against a pile of desk clutter, "a theorist is allowed to introduce one tooth fairy into his theory — but only one."

Before a 1991 conference in Annapolis, Maryland, he recalls, the scientific community was tipped 99 to 1 between those who disputed and those who accepted bursters at cosmological distances. Persuasive observations from the Compton Gamma Ray Observatory, launched earlier that year, ended the convention with the group split 50/50. "Astrophysicists are basically human," Paczynski shrugs, "so when it comes to giving up pet ideas we're as reluctant as everyone else. But I'm amazed at how many ad hoc assumptions some people were willing to make in order to keep bursters in the galaxy. Why bother?"

The enigma was deepened not just by the iffy observations but by the transient and inconsistent nature of the bursts themselves. "Any theory that explained all the observations had to be wrong" laughs Paczynski, "because some of the observations were wrong." Even the widely respected Martin Rees of Cambridge, Britain's Astronomer Royal, offered Paczynski 100-to-1 odds that bursters were not cosmological. Paczynski declined the wager, prompting Rees later to quip, "We were both fools."

Yet with a truly great man's lack of hubris, the energetic Princeton professor now admits that his early conclusions were based on incorrect evidence. He regards as undeserved the credit given him for placing bursters where they properly belong. He sighs, "I was lucky."

While the controversy raged, new satellites attempted to study the strange creatures. About 300 a year continued to pop, and the Compton Observatory, with its octet of burst detectors (called BATSE), kept catching them in the act.

The problem was that BATSE couldn't pinpoint their locations accurately enough for truly large telescopes (which have tiny, pinhole-like eyesight) to be focused exactly on target. So as the years dragged on, not a single burst could be associated with a celestial object at any other wavelength. Not one optical counterpart was found where bursts had gone off. Nor was there anything at radio wavelengths or in the ultraviolet. Either these bizarre creatures gave off only gamma rays (which is as odd as the sun emitting green light and oduce one tooth fairy into his theory — but only one."

nothing else) or else we kept failing to turn a powerful enough instrument to the right spot at the right time.

The right time. Paczynski checks his watch and taps his foot excitedly as he receives reports of observatories trying to observe the latest burst. The right time. That was the key. If these objects were so transient that they'd usually vanish faster than you could say "peculiar," maybe something else would linger, like a Cheshire cat's smile, in the spot where they once stood.

FINDING THE KEY

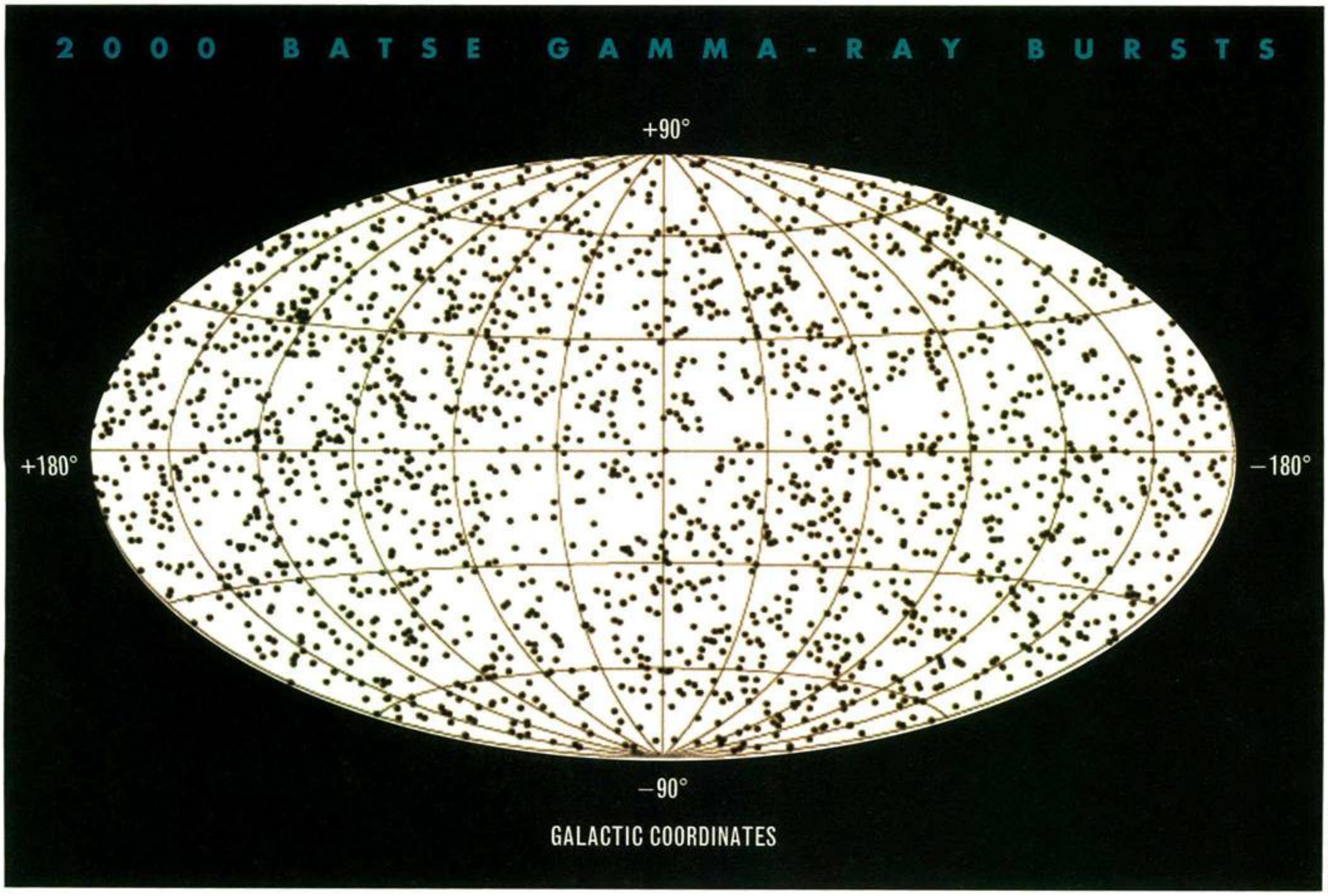
Enter the new Italian/Dutch satellite with the cryptic name BeppoSAX (an acronym even more obtuse than most, since it's derived from non-English words). The insuperable problem was time — and BeppoSAX provided it. With sensors capable of better pinpointing a burst and the ability to hop to it within hours instead of days, ground-based observatories could now swing their instruments and see if anything was there.

On February 28, 1997, it finally happened: BeppoSAX delivered its first quick and accurate position for a burst. When x-ray and other instruments checked it out, this burst (and subsequent ones on April 2 and May 8) displayed an afterglow at other wavelengths. Three continued to gleam in x-ray "light," two at optical wavelengths, and one at radio wavelengths. At last, the rest of astronomy's arsenal could pounce on the burst bandwagon.

The 15-second-long May 8 burst really did the trick, since BeppoSAX provided an accurate enough position for the 10-meter Keck Telescope to swing into action. It found a 20th-magnitude point source at the burst's location embedded in a galaxy-looking smudge. The dot was a million times fainter than the dimmest thing visible to the naked eye — but that was bright enough to take the first-ever burst spectrum at optical wavelengths. It revealed an intervening gas cloud so redshifted that it must lie several billion light-years from Earth. This means that the source, the burster, lurks farther still. Except for a handful of diehards who are saying "Not so fast," the astronomical community was finally convinced: This burster sits at least eight billion light-years away, more than halfway to the edge of the universe.

To appear so bright at such distances, the energy output of bursters has to be mindboggling. Consider: In a single second, a burster emits more power than the sun has given off in all the five billion years since its birth. Such unimaginable energy, channeled into a fraction of a second, is like some cosmic photographer setting off a flash that makes a supernova seem like a car backfiring. It's an energy pulse that stretches clear across the universe.

Nobody, neither Paczynski nor anyone else, knows what can produce that kind of power. Of course, this doesn't stop theorists from guessing. Paczynski favors the notion that an ultra-powerful magnetic field enhances, focuses, and channels some kind of energy release so that it's aimed our


2000 BATSE GAMMA-RAY BURSTS

NASA/MSFC

"The 250 lensing events detected are probably invisi

way. If pointed toward us like a laser beam, less power is emitted than if such energy were flying off every which way. In that case, explanations that involve collisions between neutron stars can be made to work. We're spared the possible hassle of coming up with a new set of physical laws.

It's still amazing, though. In an ordinary supernova, 99 percent of the energy goes into neutrinos. One percent of a supernova's power goes into the kinetic energy of the blast. Only one percent of one percent gets converted into light.

Because neutrinos are the big by-product of supernovae, theorists tried to tap them as energy transmitters for bursters, says Paczynski. But now theorists have given up; neutrinos just don't produce enough of a bang. He thinks Martin Rees is on the right track in suggesting that some kind of fireball (maybe from an ultra-strong supernova, called a hypernova) produces a gamma-ray burst when its shock wave interacts with surrounding gas, and ultrastrong magnetic fields extract and channel some of this energy like a kind of cannon.

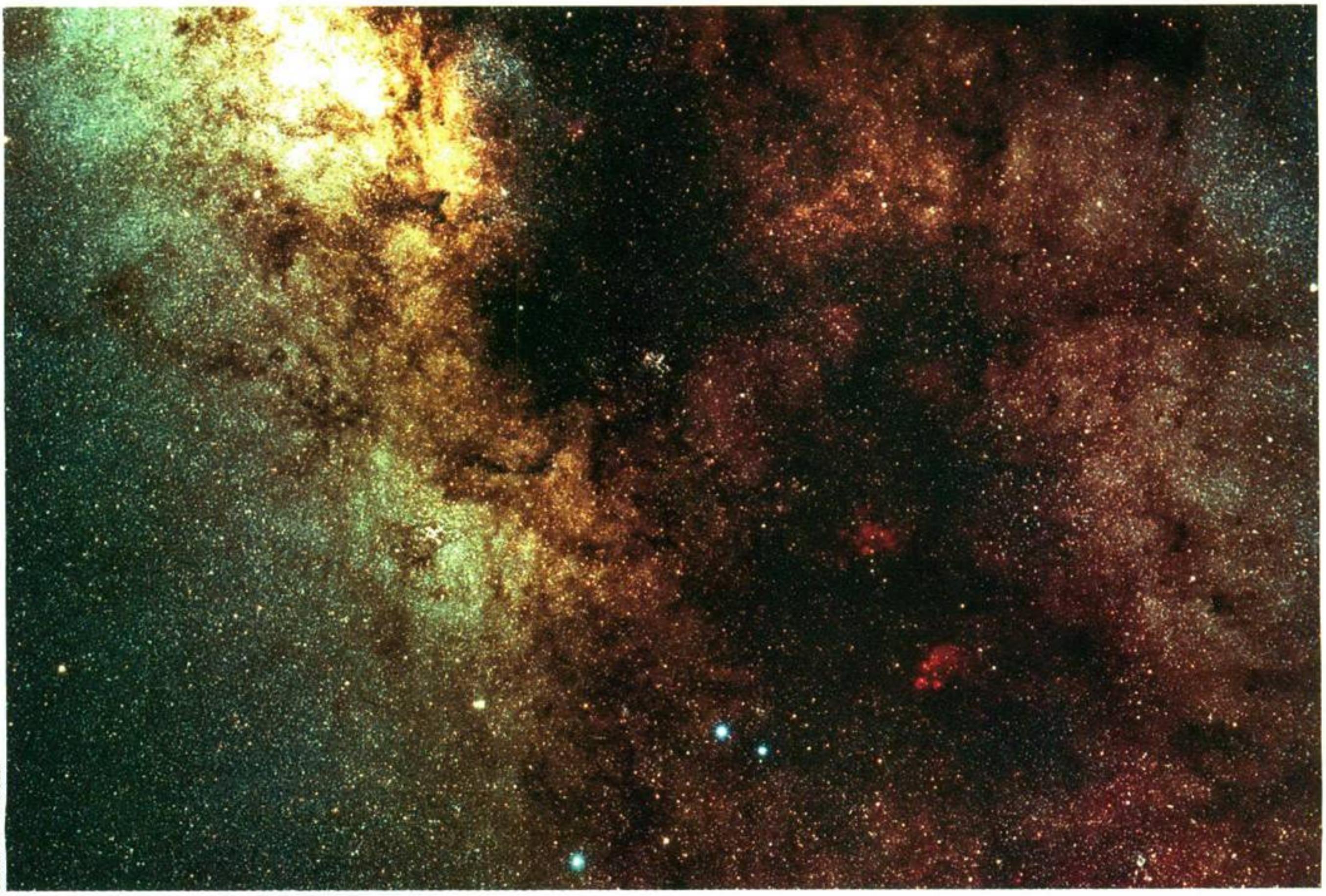
While this overall picture seems attractive and reasonable, nobody has yet been able to figure out such particulars as how to produce the fireballs in the first place. And there it sits. The mystery of where they are is apparently solved. The mystery of what they are remains.

A HINT OF DARK MATTER

But if gamma-ray bursters are weird, then Paczynski's other claim to fame — his favorite project and personal brainchild — is weirdness squared. Imagine: You start with Einstein's amply proven fact that gravity can warp space. Then, suggested Paczynski a decade ago, you use that curved space to find the hidden dark matter in our galaxy. Simple.

Within a few years, to Paczynski's surprise, new technology allowed researchers to do exactly that, and teams from four countries, including a group of Polish astronomers working with Paczynski, got to work. The idea was to ignore truly massive objects such as galaxies that really do a number on their surrounding space. While such funhouse distortions are amazing cases of gravitational lensing, what Paczynski had in mind was microlensing. That is, he suggested surveying tens of millions of stars in a crowded region. His project, called OGLE, chose the direction of our galactic center; a Berkeley-based team called MACHO picked our companion galaxy, the Large Magellanic Cloud. By repeatedly checking the light of each of these millions of suns, he reasoned, sooner or later a few of them must pass behind an unseen foreground object and have its light distorted. If the alignment was exact, there'd be a glowing halo, the bizarre Einstein Ring. A less precise line-up would force the background star into a series of eerie, distorted crescents surrounding the invisible foreground whatever-it-was.

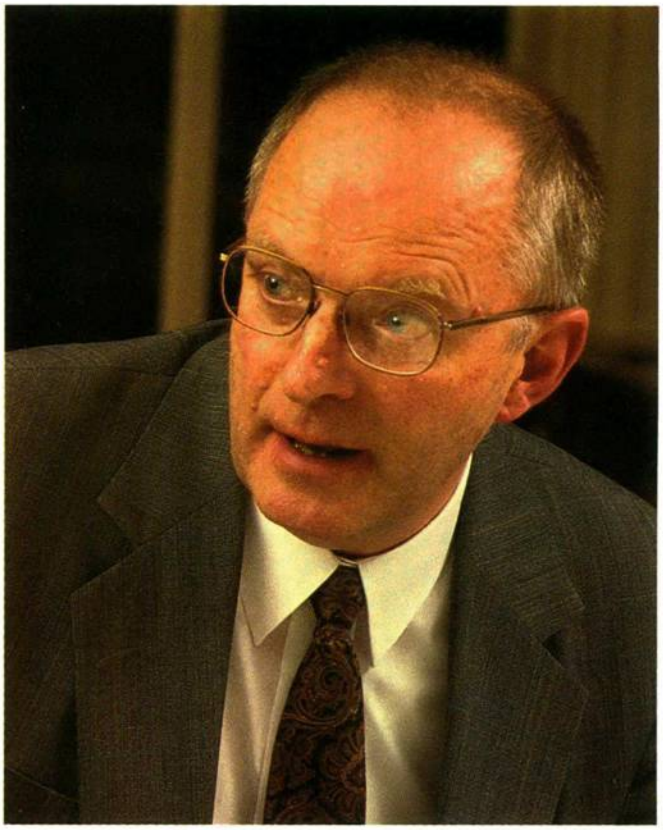
Paczynski knew there'd be no way to directly see those lensed star fragments, spaced apart by just a thousandth of an arcsecond. But as multiple images magically appeared, a



The OGLE project surveys tens of millions of stars near our galaxy's center looking for brightness changes that would signify dark matter.

Carl and Chris Weber

bly faint but ordinary stars."



Jon Goel

Paczynski has played a key role in our understanding of where gamma-ray bursts reside and what microlensing tells us about the universe.

characteristic brightness change should be detectable by simply measuring the star's brightness.

Okay, not so simple. Monitoring tens of millions of stars daily isn't the kind of thing you'd want to attempt in your spare time. But CCDs and sophisticated computer programs do it automatically. Not surprisingly, the first thing such intense photometric surveys found was a zillion new but mostly ordinary variable stars, which made Paczynski perfectly happy. Remember, he loves things that wink and blink and was in bliss simply uncovering myriad new RR Lyrae and Cepheid variable stars.

The first couple of years of the microlensing projects were spent on tedious tasks like taking background readings and finding and removing instrumental errors. "It takes years, so you want to be persistent rather than excited," he notes. Then in the fall of 1993, the first actual lenses were discovered almost simultaneously by three groups of researchers.

What are these unseen bodies? With one data point taken per night, the technique is insensitive to both very short and very long lensing events. Because low-mass objects produce shorter events and because the procedure best detects phenomena lingering from 10 to 100 days, the project was expected to uncover microlensing caused by objects with a few tenths of the sun's mass. Since that's exactly what most ordinary stars weigh, you can easily follow Paczynski's conclusion that "while it's still ongoing and preliminary, the 250 lensing events detected over the past four years are probably not strange new exotic material, but invisibly faint but ordinary foreground stars."

You make billions of measurements, and all you find are plain-vanilla red dwarfs, the street dogs of the galaxy. A bummer? A letdown?

No way. If we still don't know what most of the universe is made of, there are other fish being fried here. First, the results prove that microlensing really works. We're only at the dawn of its discoveries. Second, the number of lensing events has shown more material than expected in the direction of the galactic center, evidence that we really do live in a barred spiral and that the central bar is more or less pointed in our direction. Third, the search for dark matter is so fashionable, it helps keep these microlensing projects funded.

JUGGLING THE COSMOS

Unfortunately, things like funding and legal issues intrude on Paczynski's time, as became evident when he shed light on his involvement with the new 1.3-meter Warsaw Telescope at Las Campanas, Chile, which became fully automated in June 1997. Developed a mere two years ago under a Memorandum of Understanding signed by representatives of the Carnegie Observatories, Princeton University, and Warsaw University, it is "operating like a marvel — making up to 50 million photometric measurements every clear night," Paczynski exclaims.

But his ability to calculate the bending of space hardly helped him grasp the unforeseen hassles that threatened to delay the project: "A major hang-up was wrangling over liability. Attorneys kept worrying about things like, 'what if a Polish visitor, arriving via Princeton, touched a bare wire and electrocuted himself in Chile. Who was responsible?'" Their heads spun like neutron stars over such questions until Paczynski himself helped forge a compromise between Princeton and Carnegie lawyers.

Between bursters, microlensing, the Warsaw Telescope, and legal issues, it sounds like Paczynski juggles a fair share of the cosmos.

"My role is difficult to define," he confides. "Essentially it's a double function: To suggest scientific projects to the observers and to provide funds to carry the projects out. I think I am vastly more successful in the first than in the second. I think that over the last three or four decades I was never short of good ideas, but I always had a problem convincing reviewers that my proposals were worth funding."

The decision to emigrate permanently "just happened," he says, explaining that he was very lucky to be allowed to travel to the United States with his family. On one such occasion, in 1981, he was invited to Caltech to spend one year as Sherman Fairchild Distinguished Scholar for the second time, a rare honor. In December of that year, the communist government in Poland declared martial law, a situation that led the family to stay in the United States "a bit longer." A decade later they became citizens.

Poland's loss, our gain, Princeton's pride — where, from his home base at the university he inspires the search for new things that blink and change — enables the rest of us to follow him through the portal of cosmic discoveries. ■

Bob Berman is author of Secrets of the Night Sky *(HarperCollins). His latest book,* Cosmic Adventure, *will be published this fall by William Morrow. His previous article for* Astronomy *was "Turning Familiar into Fantastic" in the January 1998 issue.*

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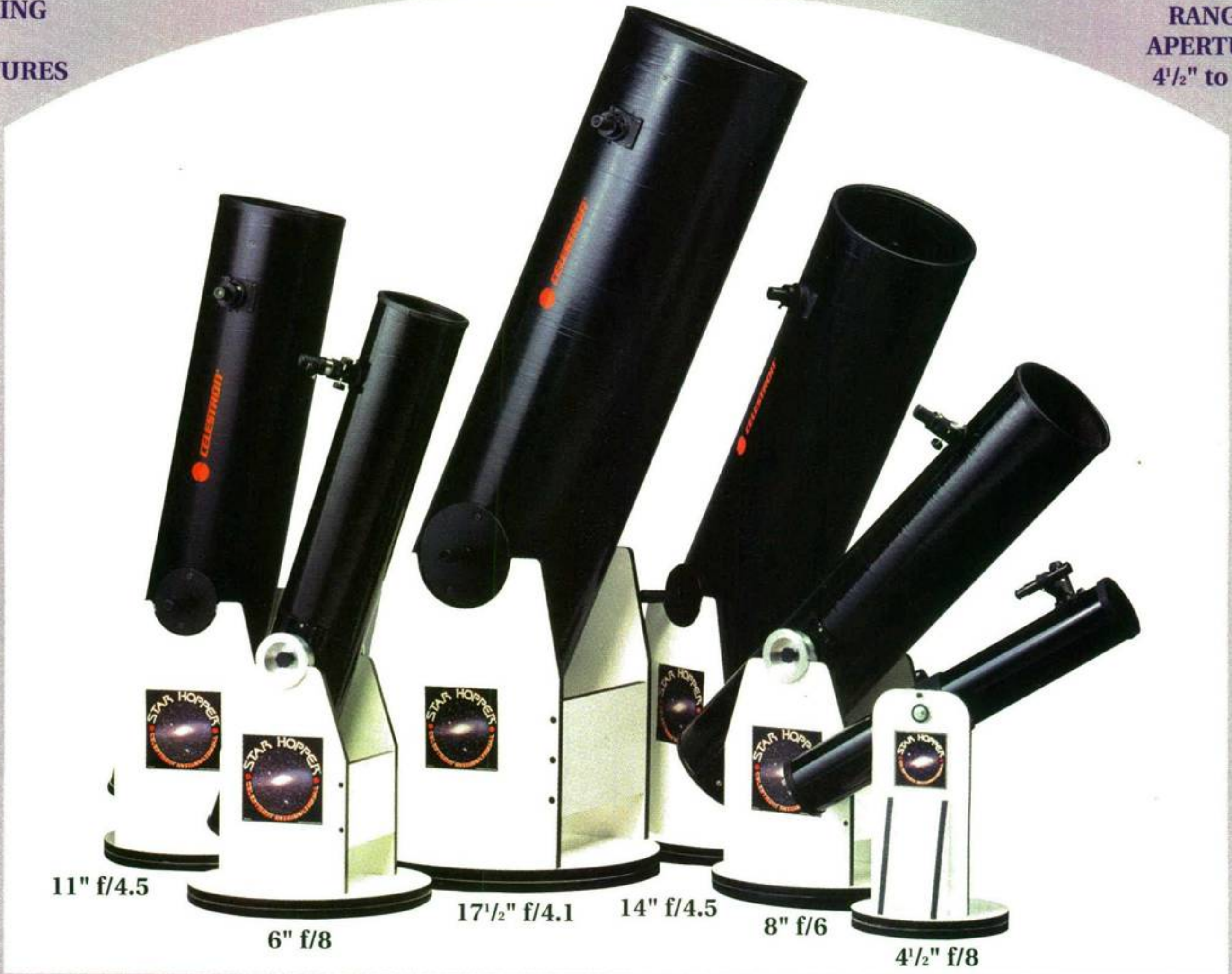

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- 6x30 Finderscope
- Unique Single-Arm Fork Mount with Carrying Handle
- Weight: 23 lbs. (including the wedge)
- Made in the U.S.A.
- The C5+ can even be converted to a computerized telescope with optional accessories.

ULTIMA® 9¼ and ULTIMA® 11

- The compact Schmidt-Cassegrain design makes these powerful telescopes portable enough to load in your car and take out to your favorite observing sites. Further, this design is user-friendly, so even a beginner can enjoy using a large telescope.
- The images captured by these versatile telescopes are superb, due to optics designed to perform flawlessly.
- 9¼" (235mm) Aperture, 11" (279mm) Aperture
- 9¼" Focal Length of 2350mm, 11" Focal Length of 2800mm
- Focal Ratio of f/10
- Starbright® Coatings
- 6x30 Finderscope – 9¼", 7x50–11"
- Hand Controller
- Focusing Micrometer on 9¼"
- PEC Electronics
- Ergonomic, user-friendly operation is the trademark of the Ultima® telescopes. The Ultima 9¼ and 11 telescopes were designed with functional use as a top priority, and they deliver.
- Standard 1¼" Accessories Include: 25mm SMA Eyepiece (94x) and Star Diagonal, 26mm Plössl (108x) for 11"
- Adjustable, Rigid Metal Tripod, Heavy Duty Wedge and Deluxe Latitude Adjuster.
- Weight: 74 lbs. for 9¼", 80 lbs for 11"
- Made in the U.S.A.
- The superb optics use high transmission Starbright® coatings to capture the brightest, sharpest images.
- The newly designed fork tines of the mount and drive base are sand cast and they add greater stability.
- The totally cordless DC servo quartz drive system runs on an ordinary 9 volt battery.
- Celestron's optional Advanced Astro Master® can be added to create a computerized telescope.

ULTIMA® 11 **ULTIMA® 9¼**

CELESTRON® *For more detailed information on these telescopes, contact a Celestron dealer or Celestron. Visit our Web site at http://www.celestron.com*

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CELESTAR 8 TELESCOPES

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CELESTAR 8

- An economical but full featured 8" Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8 to offer the **lowest price ever** on a Celestron fork mounted 8" with so many features.
- No sacrifice was made in the optics. The unsurpassed superior quality Celestron hand-figured system delivers diffraction-limited optics. Starbright® coatings are standard.
- The electronics are DC for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the *Sky & Telescope* review — "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 is powered by a 9 volt alkaline battery.
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90°.
- The new and unique Wedgpod is a combination tripod and wedge. It has a fixed height (33") and is lightweight without compromising its stability.
- Made in the U.S.A.
- Standard accessories included: 6x30 Finderscope, Star Diagonal – 1-1/4" and a 25mm SMA Eyepiece – 1-1/4" (81x).

CELESTAR 8 DELUXE

- This telescope utilizes the same superior optics used in all of Celestron's 8" Schmidt-Cassegrain telescopes and has all of the features of the Celestar 8, but is enhanced, for those who prefer a premium version of the spectacular Celestar 8.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging.
- The standard accessories for this telescope include: a Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod that's exceptionally rigid and sturdy, with adjustable height.
- Also standard is a large 9x50 Finderscope, and a multi-coated 26mm Plössl Eyepiece – 1-1/4" (78X).

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Advanced Astro Master

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The Celestar 8 Computerized and the Celestar 8 Deluxe Computerized telescopes are the same as the Celestar 8 and Celestar 8 Deluxe but with the addition of a factory **installed** and **tested** Advanced Astro Master®.

The pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9 volt battery.

Contains an RS-232 serial interface to enable usage with PC programs like "The Sky"™ by Software Bisque.

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THE SKY SHOW

The summer solstice offers long days and short nights, making deep-sky observing difficult. Turn your eyes and telescopes toward the outer planets. Uranus, Neptune, and Pluto are at their best this month.

By Martin Ratcliffe and Alister Ling

▶ The elusive planets are easy to find this month. **Mercury**, **Uranus**, and **Neptune** each make their presence obvious by wandering near to bright stars. Even if you're not familiar with the constellations, it's worth trying to spot these three planets while the odds are in your favor.

Ephemeral Mercury makes a brief but notable early evening appearance late in June. This apparition is arguably the best of the year, since the planet is visible for about a month. On June 5 Mercury passes its ascending node through the ecliptic plane. This places the planet at a northerly declination that favors Northern Hemisphere observers. Following its superior conjunction with the sun on June 10 Mercury begins to set later and later each night. By June 21 it sets an hour after the sun, making this the first evening to easily spot the planet. Mercury reaches its greatest elongation east of the sun (27°) next month (July 16).

Finding Mercury should be easy during the last week of June. The two principle stars of Gemini the Twins (Castor and Pollux) will assist you. Starting on June 22, Mercury will lie below these first magnitude stars. A thin sliver of a two-day old moon lies 8° to the left of Mercury on June 25. On June 28, a line drawn from Castor through Pollux will appear to point toward the magnitude –0.6 planet. By the end of June, Mercury sets more than an hour after the sun. This gives the sky plenty of time to darken, allowing the planet to become more conspicuous. Through a scope, Mercury's shimmering, gibbous phase spans a mere 6".

Much later in the night, Uranus can be readily identified by anyone who owns a pair of binoculars. Really. This is your chance to spot the seventh planet from the sun while it is 1.7 billion miles (2.8 billion kilometers) away. During June, Uranus

The dark, dry skies of the desert Southwest can offer an excellent night of observing. Such conditions are welcomed in a month of long, hazy days and short nights. Here the "trees" of the Sonoran Desert provide the foreground to the trails of stars.

Eric DeBolt

JUNE 1998

1 First quarter moon is at 9:45 p.m. EDT

4 Asteroid Hebe is at opposition, 8 a.m. EDT
The moon is at apogee (251,609 miles from Earth), 7:44 p.m. EDT

9 Asteroid Vesta is in conjunction with the sun, 3 p.m. EDT

10 Full moon is at 12:18 a.m. EDT
Mercury is in superior conjunction, 3 a.m. EDT

13 Asteroid Melpomene is at opposition, 4 a.m. EDT
The moon passes 2° north of Neptune, 8 a.m. EDT

14 The moon passes 3° north of Uranus, 4 a.m. EDT

17 Last quarter moon is at 6:38 a.m. EDT
The moon passes 0.8° south of Jupiter, 7 a.m. EDT (page 77)

19 The moon passes 2° south of Saturn, 4 p.m. EDT (page 77)

20 The moon is at perigee (227,790 miles from Earth), 1:23 p.m. EDT

21 The moon passes 3° south of Venus, 10 a.m. EDT (page 77)
Summer solstice is at 10:03 a.m. EDT

22 The moon passes 0.4° north of Aldebaran, 10 a.m. EDT

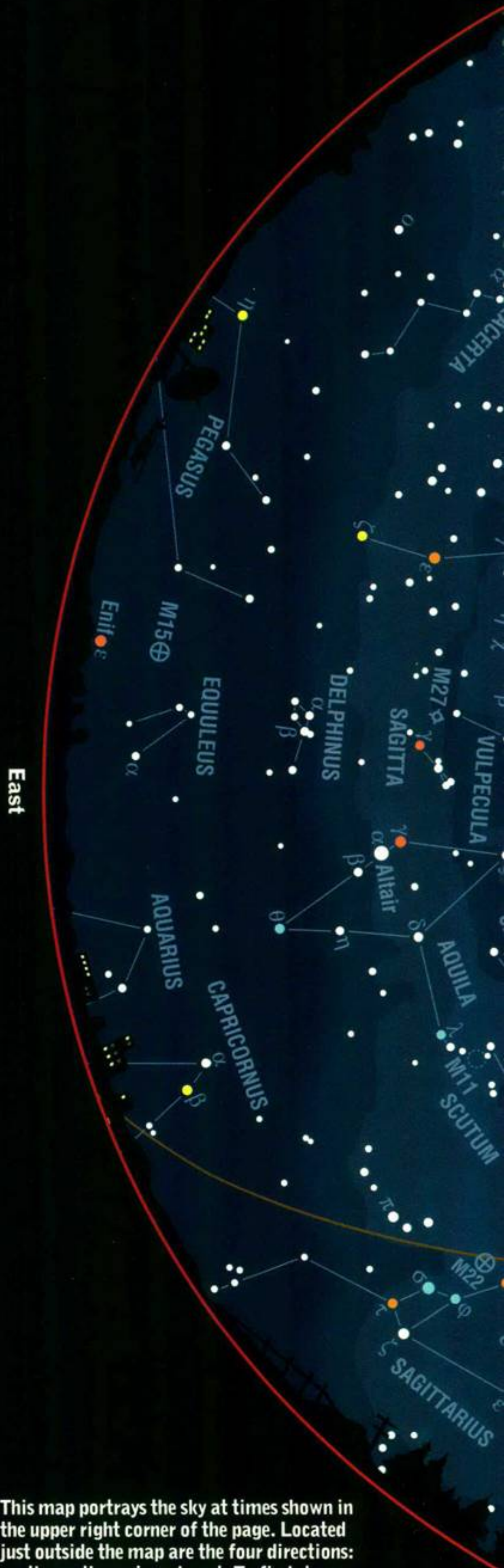
23 New moon is at 11:50 p.m. EDT

25 The moon passes 5° south of Mercury, 9 a.m. EDT

27 Mercury passes 5° south of Pollux, 7 a.m. EDT

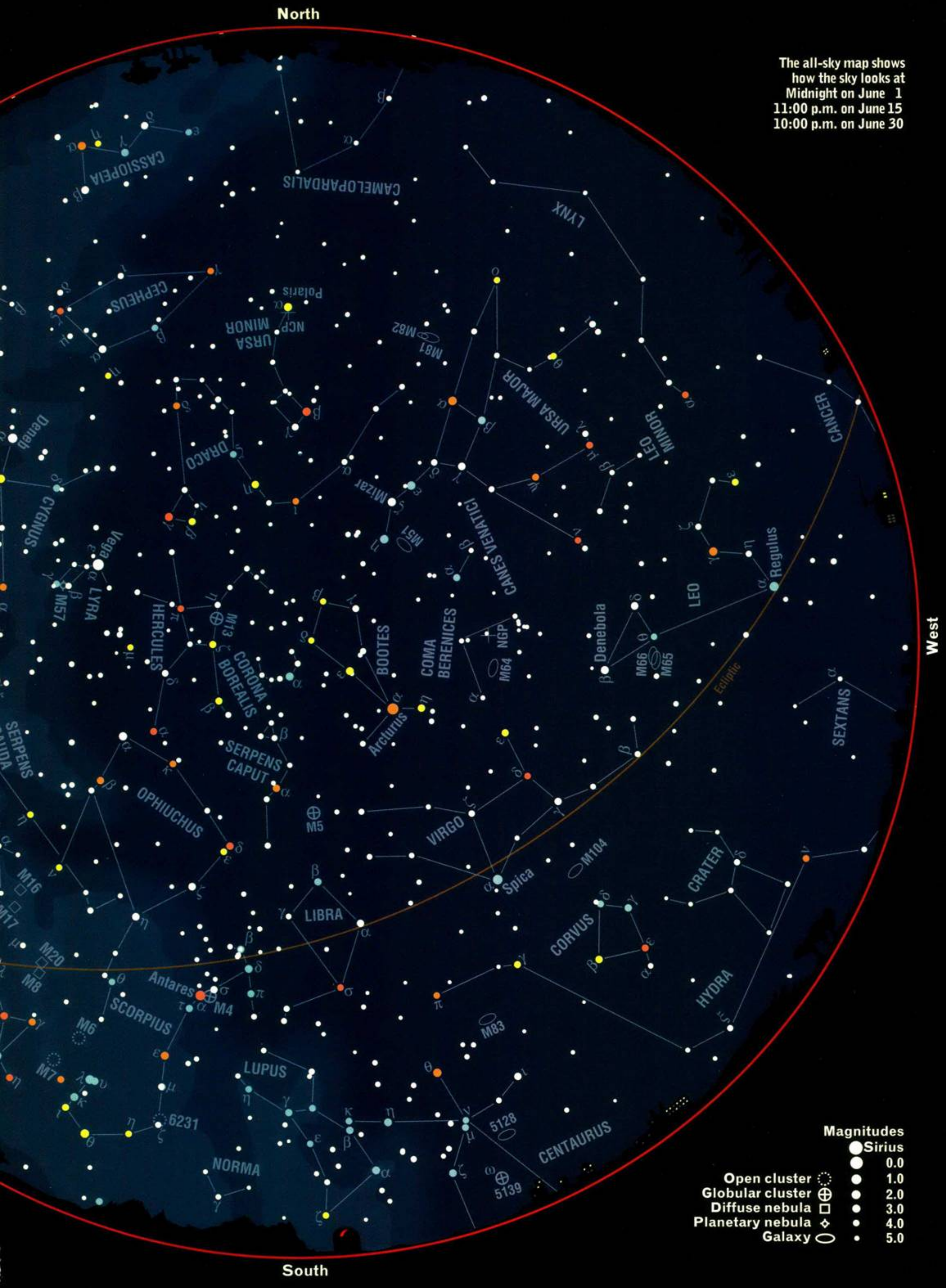
28 The moon passes 0.8° south of Regulus, 8 a.m. EDT

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1 🌓	2 🌔	3 🌔	4 🌔	5 🌔	6 🌔
7 🌕	8 🌕	9 🌕	10 🌕	11 🌕	12 🌕	13 🌕
14 🌖	15 🌖	16 🌖	17 🌗	18 🌘	19 🌘	20 🌘
21 🌘	22 🌘	23 🌑	24 🌑	25 🌒	26 🌒	27 🌒
28 🌒	29 🌒	30 🌓				

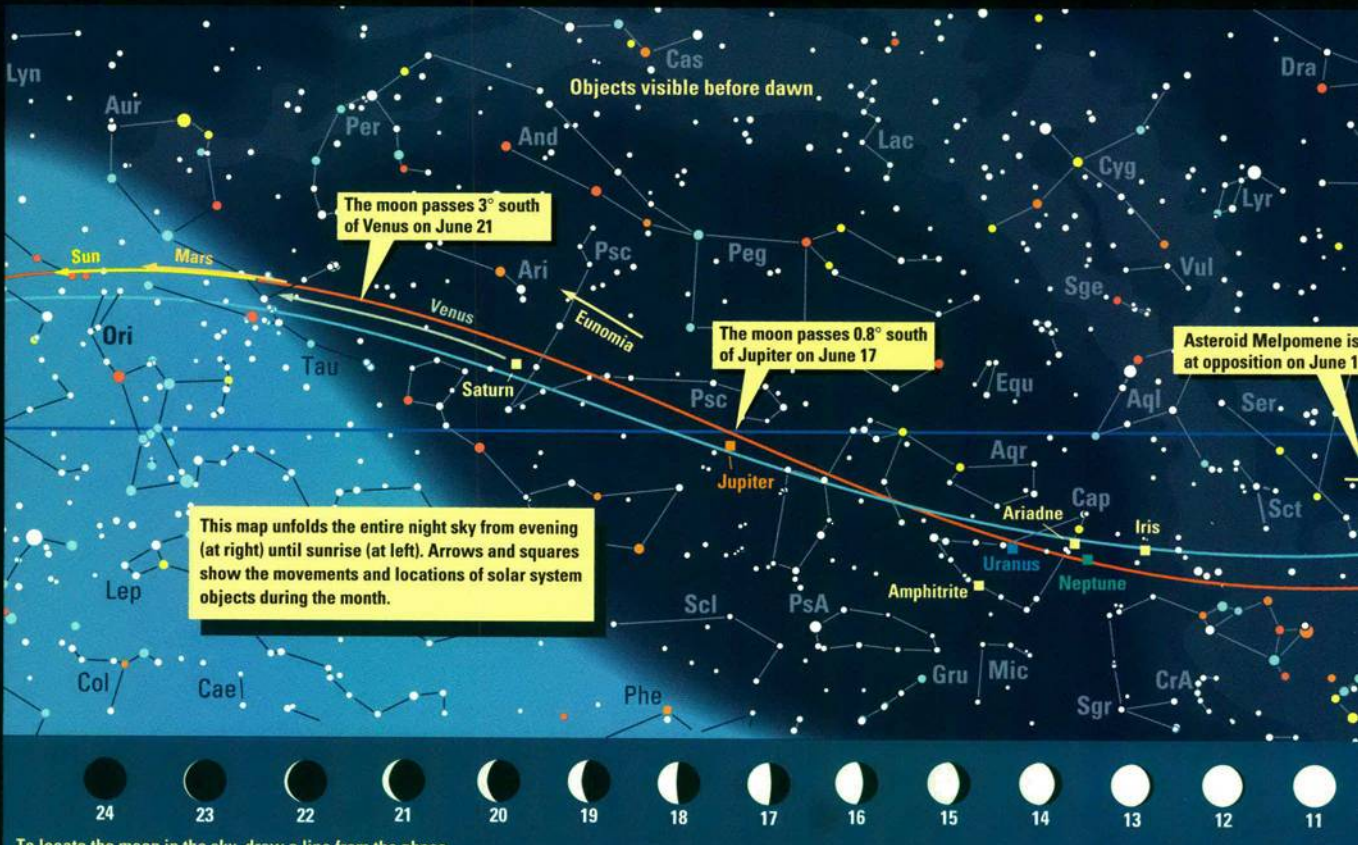


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows
how the sky looks at
Midnight on June 1
11:00 p.m. on June 15
10:00 p.m. on June 30


North
South
West
CASSIOPEIA
CAMELOPARDALIS
LYNX
CEPHEUS
Polaris
NCP
URSA MINOR
M82
M81
URSA MAJOR
LEO MINOR
CANCER
Deneb
DRACO
CYGNUS
Mizar
M51
CANES VENATICI
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
BOOTES
COMA BERENICES
NGP
M64
Denebola
M66
M65
LEO
Regulus
Ecliptic
SEXTANS
SERPENS CAUDA
SERPENS CAPUT
Arcturus
OPHIUCHUS
M5
VIRGO
M104
Spica
CRATER
CORVUS
M16
M17
M20
M8
LIBRA
Antares
M4
SCORPIUS
M6
M7
HYDRA
M83
LUPUS
6231
5128
CENTAURUS
NORMA
5139
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Lyn
Aur
Per
Cas
And
Lac
Cyg
Lyr
Dra
Psc
Peg
Ari
Sun
Mars
Venus
Eunomia
Ori
Tau
Saturn
Psc
Jupiter
Equ
Aql
Ser
Sge
Vul
Aqr
Cap
Ariadne
Iris
Sct
Uranus
Neptune
Amphitrite
Lep
Scl
PsA
Col
Cae
Phe
Gru
Mic
Sgr
CrA
24
23
22
21
20
19
18
17
16
15
14
13
12
11

Objects visible before dawn

The moon passes 3° south of Venus on June 21

The moon passes 0.8° south of Jupiter on June 17

Asteroid Melpomene is at opposition on June 1

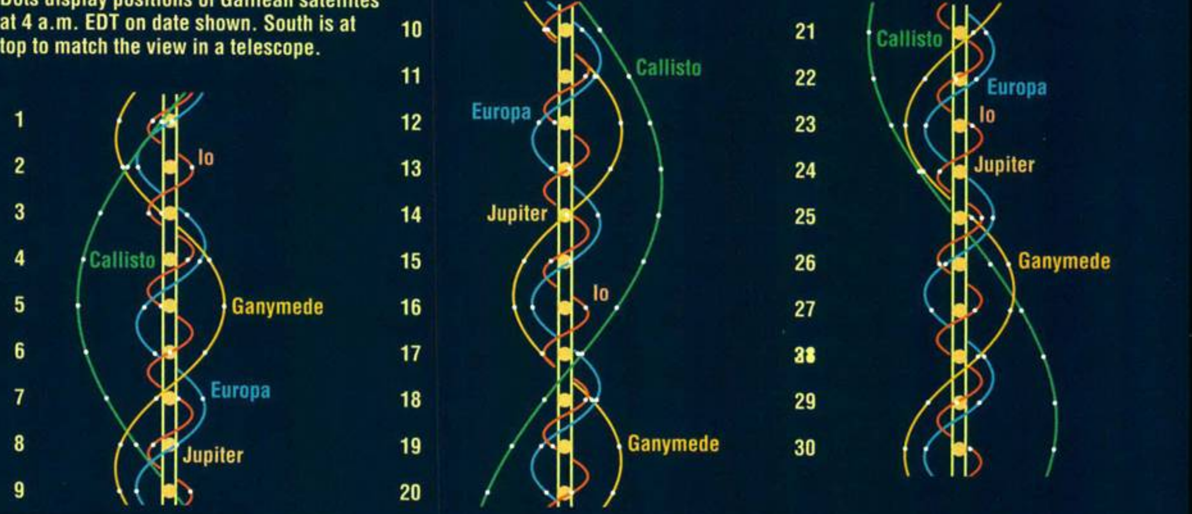
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

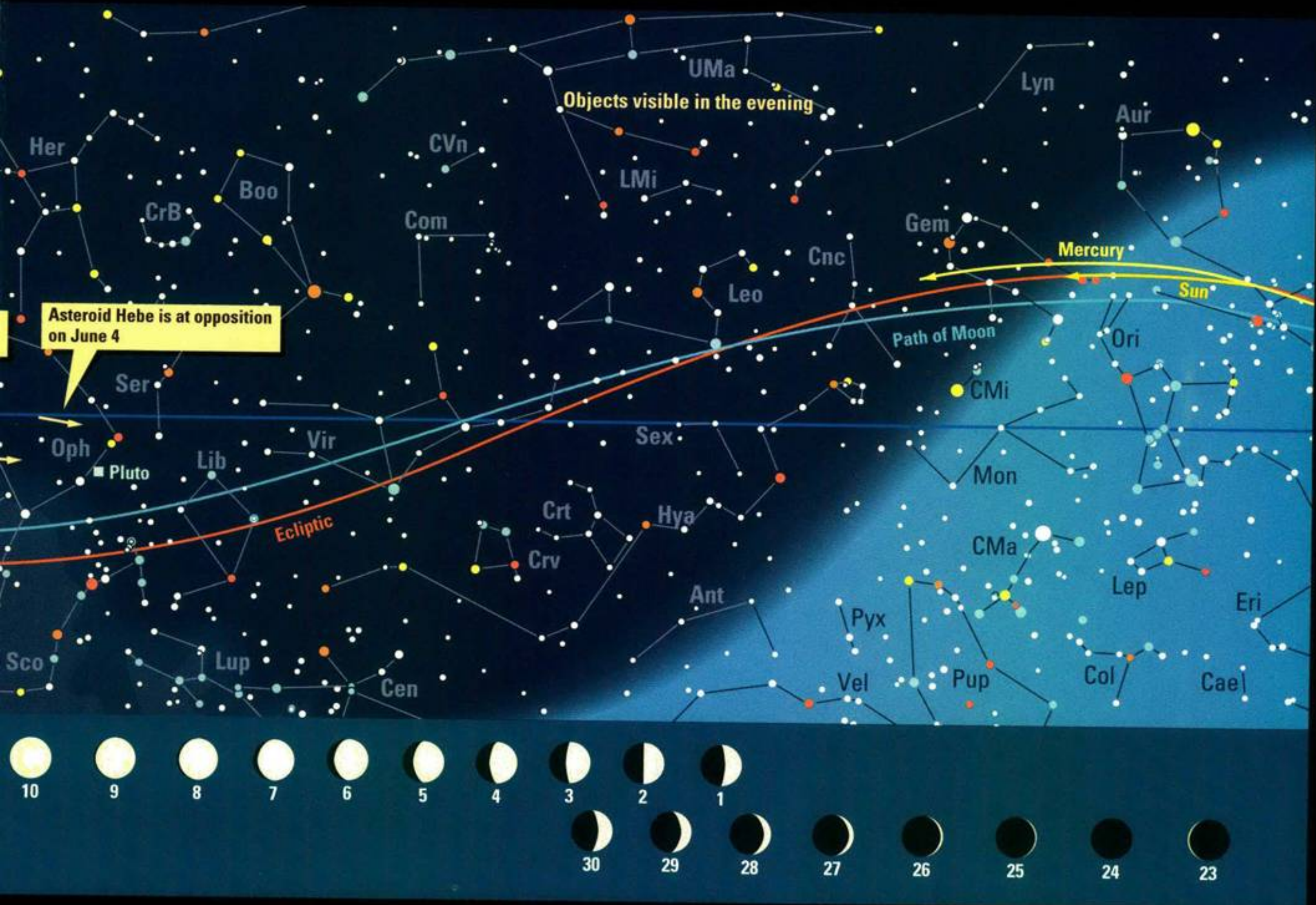
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	June 1	June 30	June 15	June 15	June 15
Magnitude	–1.2	– 0.3	– 4.0	1.5	–2.4
Angular Size	5.3"	6.0"	13.2"	3.7"	40.0"
Illumination	90%	71%	80%	100%	99%
Distance (AU) from Earth	1.263	1.120	1.266	2.518	4.926
Distance (AU) from Sun	0.331	0.392	0.727	1.520	4.983
Right Ascension (2000.0)	3h49.2m	8h03.6m	3h07.5m	4h56.3m	23h48.6m
Declination (2000.0)	19°15'	22°11'	15°33'	23°01'	–2°32'

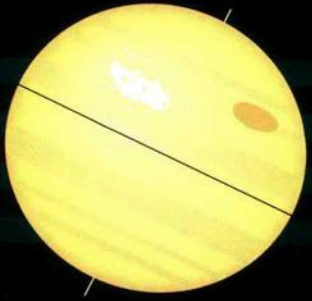
JUPITER'S MOONS

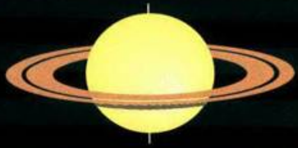
Dots display positions of Galilean satellites at 4 a.m. EDT on date shown. South is at top to match the view in a telescope.




Objects visible in the evening
UMa
Lyn
Aur
Her
CVn
LMi
Boo
CrB
Com
Gem
Mercury
Cnc
Leo
Sun
Path of Moon
Ori
CMi
Ser
Sex
Oph
Vir
Mon
Pluto
Lib
Crt
Hya
Ecliptic
CMa
Crv
Lep
Ant
Eri
Pyx
Sco
Lup
Cen
Vel
Pup
Col
Cae
10
9
8
7
6
5
4
3
2
1
30
29
28
27
26
25
24
23

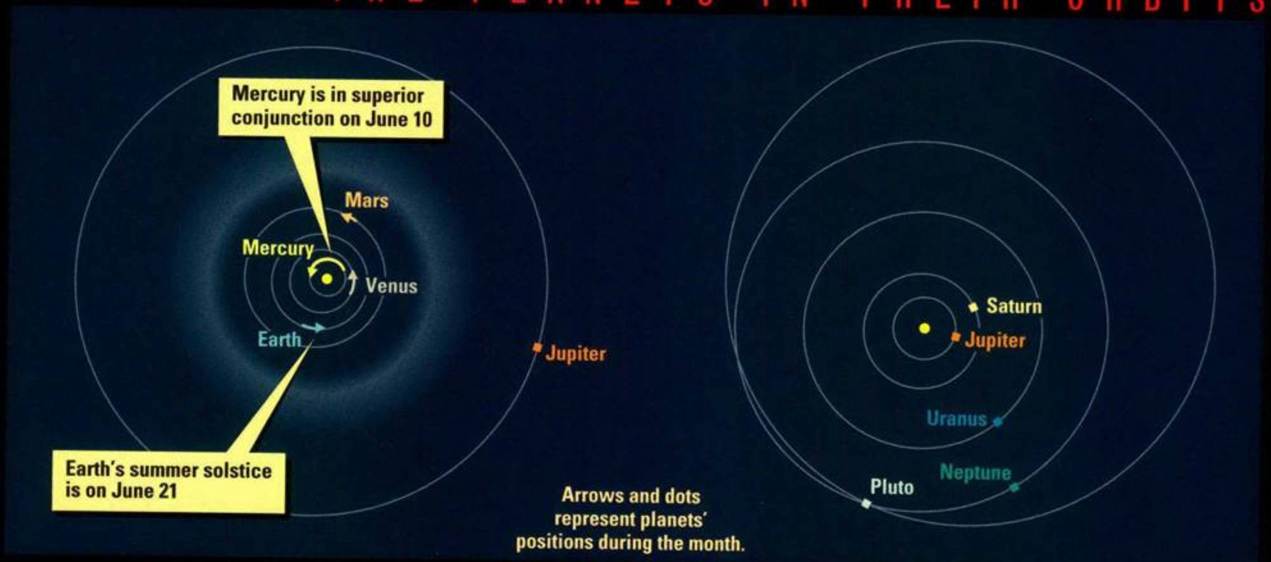
Asteroid Hebe is at opposition on June 4





SATURN	URANUS	NEPTUNE	PLUTO
June 15	June 15	June 15	June 15
0.4	5.7	7.9	13.7
16.8"	3.7"	2.3"	0.1"
100%	100%	100%	100%
9.895	19.179	29.333	29.121
9.322	19.864	30.140	30.070
1h57.2m	21h00.4m	20h15.6m	16h26.0m
9°29'	–17°42'	–19°26'	–9°09'

THE PLANETS IN THEIR ORBITS


Mars
Mercury
Venus
Earth
Jupiter
Saturn
Jupiter
Uranus
Neptune
Pluto

Mercury is in superior conjunction on June 10

Earth's summer solstice is on June 21

Arrows and dots represent planets' positions during the month.

FIRST VIEW: Lyra's Binocular Doubles

Have you ever thought of approaching the sky like you would a country filled with national parks? There are some places where the view is incredibly breathtaking, others that spark one's imagination, some that are notable for their starkness, and still more that leave one relaxed and contented.

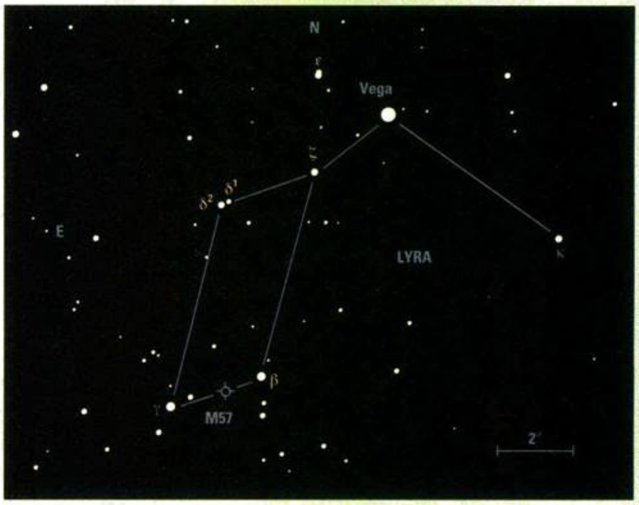
Observers like to visit Lyra chiefly for its two best tourist traps: the Ring Nebula (M57) and the Double Double (Epsilon [ε] Lyrae). Both are great through a telescope, but on your next visit put on a new pair of glasses for a completely different perspective.

With a pair of binoculars, you can actually stare at Vega with both eyes open and enjoy its blue-white brilliance set against the dark sky. In the same field of view, the wide pair of the Double Double provides a delightful punctuation. This identical pair is separated by 3.5', but you won't see each pair split into two distinct stars — accomplishing that requires a scope.

Rick Albrecht

Zeta (ζ) Lyrae is the other bright star in the same field as Vega. Hold your binoculars steadily to split this close (0.75'), pale, yellow-blue pair.

Farther south is the binary Beta (β) Lyrae. The two stars in this inseparable pair eclipse each other over a 13-day period. If you pay attention, you'll see their brightness change during this time frame. Generally, Beta is about as bright as its neighbor 3.5-magnitude Gamma (γ) Lyrae. In the space of two days, Beta drops 0.7 magnitude then rides back up to normal two days later. A secondary eclipse is not as obvious, but with some care the 0.3-magnitude drop is observable.



All illustrations by *Astronomy*: Elisabeth Rowan

If you like being charmed, pop northward to Delta (δ) Lyrae. This bright orange star sits among a handful of slightly fainter white ones. The group is now collectively known as the cluster Stephenson 1, also a delight in rich field telescopes.

These few objects offer some of Lyra's special highlights. Like any national park, many more delights await you within this constellation's starry boundaries. On your next visit, take the time to stop and see the sights instead of just driving through.

lies near the magnitude 4.1 star Theta (θ) Capricorni. Theta is the star located in the upper middle section of Capricornus the Sea Goat. The constellation rises by 2 a.m. in early June, and it clears the horizon by midnight at month's end.

Uranus was the first planet to be discovered using optical instruments. In 1781 Sir William Herschel, then an amateur astronomer and soon to become England's Astronomer Royal, discovered the long-unknown planet. Before this time, only the planets out to Saturn were known.

Since its discovery, we've used Kepler's laws of planetary motion to exactly predict Uranus's path. To find it this year, center Theta (θ) Capricorni in your binoculars. To the right-hand side of your field of view will be two faint stars close to one another. During the first week of June, one lies above the other. The faintest, uppermost object is a star. The brighter, southernmost one is Uranus. It shines at magnitude 5.7, an easy object to spot. Look at the same region night after night. The planet's motion relative to the background star will become quite obvious.

Neptune is a month away from opposition, when it will lie about 2.7 billion miles (4.4 billion kilometers) away from Earth. Even at that enormous distance, Neptune manages to glow at magnitude 7.8 in western Capricornus. Rising an hour or two before midnight, the dim bluish disk of Neptune can be found within the same low-power field as the magnitude 5.3 star Sigma (σ) Capricorni. Careful scrutiny of this region with binoculars will reveal the distant planet, especially a few nights later when it will have noticeably moved.

Earth's position in its path around the sun reaches an annual milestone this month. The summer solstice occurs on June 21 at 10:03 a.m. Eastern Daylight Time (EDT). This precision is made possible by the fact that there is an exact moment when the sun lies at its farthest point north of the celestial equator during its annual apparent path along the ecliptic. If we could see the stars during the daytime, we would find the sun at the eastern end of Taurus. Check a star atlas: The ecliptic (the path the sun appears to take through the sky) is at its maximum northern declination on this date.

A consequence of the sun being high in the northern sky is long days and short nights for those living in the Northern Hemisphere. Observers near 40° north latitude experience the earliest sunrise on June 14 and the latest sunset on June 27, with the longest day on June 21. For these observers, true astronomical darkness (defined by the sun being at least 18° below the horizon) lasts a mere four hours. The addition of a bright full moon on June 10 effectively rules out any deep-sky observing early in the month. The situation is worse for observers at 50° north latitude, where the sun never reaches more than 16° below the horizon all night. For residents at these latitudes, the sky does not completely darken — poor observing conditions, but excellent for the moon, planets, and some star clusters. For most of North America, the sky is dark by 11 p.m. local time.

Local midnight (which occurs around 1 a.m. due to daylight savings time) is the only good time to find **Pluto**, just one month past opposition. It lies 1° west of the relatively bright 2.6-magnitude star Zeta (ζ) Ophiuchi. Take the opportunity this year to use Zeta as a guide to find Pluto. Next year Pluto and Zeta will be in the same field of view, but the brilliance of Zeta will overwhelm the dim 14th-magnitude planet. This will make Pluto even more difficult to find.

Star Clusters for Bright Nights

For many amateurs, summer is not a welcome event. Latitudes north of 50° have a "perpetual twilight" as the sun performs its shallow slide under the northern horizon before fully rising again in the northeast. But this is not a time to give up.

Open star clusters can solve your bright sky problem. Individual stars in the cluster can pierce through haze and gray skies like no other class of deep-sky object. Naturally, the Messier star clusters are the most prominent and are first on the list, but let's skip those and move on to a few others that are every bit as interesting.

Possibly the easiest non-Messier cluster to find is NGC 6910, roughly 3/4° north of Gamma (γ) Cygni, the central star of the Northern Cross. This splashy group contains two lovely yellow-orange luminaries surrounded by a dash of white followers.

NGC 6910

Scott Justis

Too far south for those north of 50° latitude, but a delight worthy of highest mention, is NGC 6231 in Scorpius, just north of Zeta¹ (ζ¹) and Zeta² (ζ²). It holds more than a dozen magnitude 6-7 white stars that are crammed together with even more fainter ones. Even if NGC 6231 is a few degrees above the southern horizon it will surely impress you.

Three of my favorites lie in a line from northern Ophiuchus to western Aquila, but they require some effort to find — which explains their relative obscurity. IC 4665 is 1.5° northeast of Beta (β) Ophiuchi. Use your lowest power to best appreciate this splashy colorful clump of stars.

Those with an equatorial mount can simply swing 41' of right ascension east and some 30' of declination north to find NGC 6633. After looking at this moderately populated group, drop 1° south and slide another 11' in right ascension east to land on bright IC 4756. Both of these IC clusters escaped Sir William and Sir John Herschel because these great astronomers did not have any true low-power eyepieces. If you live in the city, NGC 6633 and IC 4756 will probably be a tough star hop. You may find it easier to aim your finder at the appropriate blank spot in the sky.

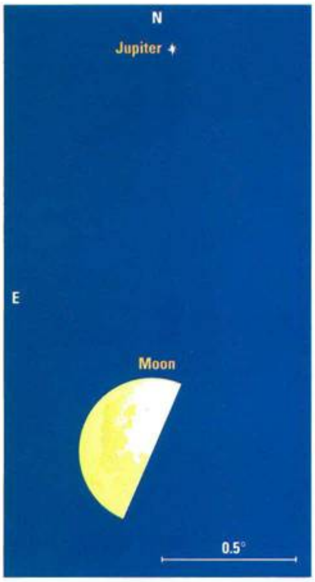
NGC 6231

Lowell Observatory

NGC 4665

Janos Papp

Jupiter Daylight Delight



You may know that it is possible to spot Venus with the unaided eye during the day. You may not realize that you can do the same for the largest planet in our solar system, Jupiter. Seeing Jupiter during daylight hours is traditionally more difficult, but it can be done with practically the same amount of effort. The first time I saw Jupiter naked eye during the day, I was shocked at how easy it was.

This month is a special time to attempt this feat. First of all, the planet lies 90° from the sun. That's smack in the middle of the sky's darkest zone — the polarization band. Here the sun's light is not as intense. This polarization of sunlight is an effect caused by tiny particles that scatter the sunlight through our atmosphere. Another reason to try finding Jupiter during daylight hours this month is the moon. On June 17, the moon's crescent can act as a guide to finding Jupiter.

On June 16 to 18, the moon does more than point you to the right place. It helps you focus your eyes properly. This sounds a bit counterintuitive, but focusing on the daytime sky is difficult. Without a point of reference, your eyes will probably be a bit out of focus. Jupiter's pale dot could easily merge into the sky's blue background.

Another secret tool in this daylight hunt is a pair of polarized sunglasses. When you turn your back to the sun, you will be struck by the deep, dark blue band arching overhead through the zenith. Smack in the middle of the band, approximately 40° above the southern horizon just after sunrise, is Jupiter.

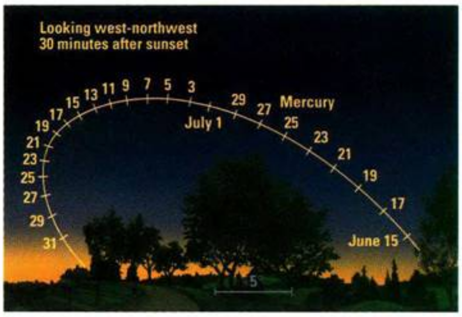
The morning of June 17 finds Jupiter a mere two lunar diameters away from the crescent moon. For observers on the east coast, Jupiter will be at the 10 o'clock position relative to the 12 o'clock line of the moon's terminator (the line separating the lit and unlit sides of the moon). To those in the west, Jupiter will be at the 12 to 1 o'clock position above the moon's crescent.

Mercury's Evening Apparition

Mercury fans will be happy to see the speedy messenger return to visibility at a more civilized hour of the day — 30 minutes after sunset or roughly 9 p.m. for a latitude of 40° north. At that time, Mercury sits about 6° above the northwestern horizon late in the month. Make sure you have no obstructions along your horizon.

This appearance is not a particularly favorable one. The sky's bright twilight glow and the planet's low altitude may hinder your view. To better your chances of spotting this planet, use binoculars. On the evening of June 25, the crescent moon will be to Mercury's left. Because the moon is below the ecliptic and Mercury is above, the two are separated by a hefty 8°.

If your telescope can scrape low enough to the horizon, Mercury will show a nearly full phase at mid-month. By month's end, Mercury's phase will change to a fat gibbous.



Returning to the late evening sky, low in the northwest the twin pair of 1st-magnitude stars Castor and Pollux perform their double disappearing act as they set below the horizon in the rapidly fading twilight. The stars of spring lie to the west of your central meridian (the imaginary line running across the sky from due north to due south while passing through the zenith).

The most obvious star visible as darkness falls is the subtle orange glow of Arcturus. Like a distant Chinese lantern, Arcturus marks the base of the kite-shaped constellation called Bootes the Herdsman (you'll find it almost in the center of our sky map on pages 71–72). From Arcturus, tilt your head down slightly to the southwest to find Spica. This star is blue-white — due to its higher surface temperature (20,000° K) compared to cooler Arcturus (4,500° K) — and is the brightest star in the constellation Virgo the Maiden. West of the central meridian, the star Regulus in Leo the Lion leads the pack of spring constellations across the dark canopy.

The summer constellations are concurrently rising in the east as they prepare for center stage in the middle of the night. Like a pair of placid birds, Altair the Eagle and Cygnus the Swan climb gracefully above the western and northwestern horizon. Cygnus is a beautiful constellation. Rich star clouds separated by the dense, dark dust clouds that pervade the Milky Way define its beauty. Within 20° of the swan's heart lie shreds of evidence that reveal the life history of stars. The relatively gentle puffs of gas that formed the Ring Nebula (M57) in Lyra

OBSERVER'S CHALLENGE: The Serpentine Ridge

This month we have a change of pace. Instead of the usual deep-sky object, we'll set our sights on the bright moon. A wide range of challenges is available in the fascinating area of the Serpentine Ridge.

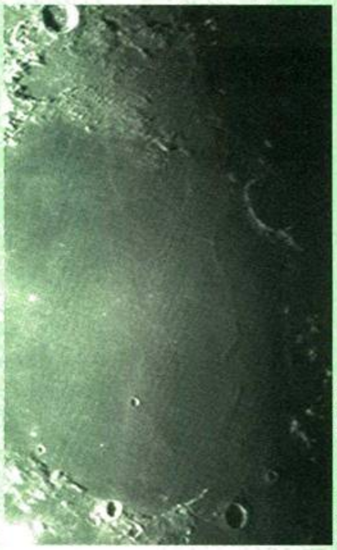
The best times to poke around this region are within a day or two after lunar sunrise (evenings of May 31 and June 29) and within a day or two before lunar sunset (morning of June 14). At these times, the sunlight angle is low and casts long shadows. This allows shallow features to be seen more easily.

The Serpentine Ridge — named Dorsa Smirnov on modern atlases — is a very long structure on the right side (celestial west) of Mare Serenitatis the Sea of Serenity. Its 200-mile (320 km) length is a complex set of wrinkle ridges, and it has a peculiar resemblance to the Veil Nebula.

Smack in the middle of the ridge lies the small crater Very, only 3 miles (5 km) across. For a tougher challenge, see if the atmosphere will let you pick out the two diminutive craters to the south.

While in the area, stop by the large and delightfully complex crater Posidonius, just north of the Serpentine Ridge. It's easy to get lost in the wonderful detail here. There are many small craters, bumps, rilles, and a second wall to explore.

The photo shows the Serpentine Ridge on the right-hand side of Mare Serenitatis. The crater Bessel is just below the Mare's center point.



Tom Johnston and Bob Ross

and the Dumbbell Nebula (M27) in Vulpecula, reveal star deaths on a massive scale.

The faint remnant of the galaxy's most violent event, a supernova divulged by the Veil Nebula (a UHC or Oxygen III deep-sky filter will help this nebula stand out in a dark sky), teaches us much about the death of stars. Giant stars like Deneb shine 60,000 times brighter than our own sun and put our star into context. Three degrees from Deneb and visible in binoculars from a very dark site, the North America Nebula represents the interstellar gas clouds that enrich our Milky Way Galaxy with the seeds from which new stars are be born.

It's a seemingly insignificant star that holds a special place in the history of the stellar distance scale — the fascinating double star, 61 Cygni. These two orange stars of almost equal magnitude (5.2 and 6.0) stars are 30" apart — an easy double for small telescopes. You can find them less than one fist-width southeast of Deneb.

The key to stellar distances was supplied by German astronomer Friedrich Wilhelm Bessel. Bessel was the director of the observatory at Konigsberg from 1810 to 1846 and was known for his observational skill. He made a general assumption that the higher proper motion stars were probably closer to Earth than those with smaller proper motion. Observing such stars over a six-month interval allows us to see the position of nearby stars relative to the distant background stars. We see them from opposite sides of our orbit around the sun. This makes the nearer stars appear to move with respect to the distant background stars. This is equivalent to the observation that, while driving down a highway, trees closer to you seem to move faster than those on the horizon. This small motion in the star's position relative to the background stars is called parallax. Following a determined 18-month campaign, in 1838, Bessel found the parallactic shift he was looking for. He observed that 61 Cygni showed a parallax of one third of a second of arc (0.33'). This placed the star about 11 light-years from Earth.

Bessel's discovery caused other astronomers to hunt for parallaxes in their observations. Thomas Henderson of the Cape Observatory found that in old observations taken six years before Bessel's, Alpha (α) Centauri showed an even greater parallactic shift — meaning the star lies at less than half the distance of 61 Cygni. The Alpha Centauri system of three stars is now recognized as the closest to the sun.

As Cygnus and Altair rise higher in the sky, the teapot shaped group called Sagittarius sneaks over the southeastern horizon by midnight. At this witching hour, the Milky Way is on fine display. If you observe from a site with a good, dark southeastern horizon, you'll see our galaxy's rich star clouds rising. One indication that this region is about to rise is given by its vanguard Antares. This beautiful red-giant star rises about an hour before Sagittarius and sits at the heart of Scorpius. Observers near 40° north latitude will find Antares sitting proudly due south roughly three fist-widths at arm's length above the horizon at midnight.

By the time Cygnus reaches a high point in the sky, dawn is not far away. On the eastern horizon the brighter planets are congregating. **Jupiter** rises with the stars of Pisces the Fish, an hour after midnight mid-month. There are no bright stars in this western region of Pisces, so the solar system's largest planet shines like a solitary diamond on black velvet. The familiar asterism called the "Circlet" lies to the north of Jupiter. The planet's easterly motion slows against the background stars during June as it prepares to begin its retrograde loop in mid-July.

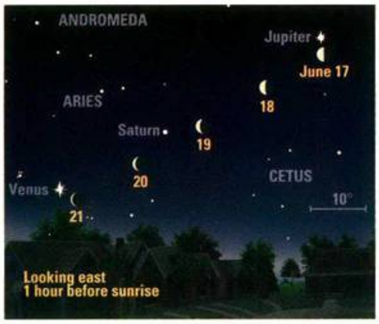
Jupiter seems to have earned an extra moon this month — it passes near the 5th-magnitude star 20 Piscium. The star is of similar brightness to Jupiter's four familiar Galilean moons (Io, Europa, Ganymede, and Callisto). Each moon appears in line with the equatorial belts of Jupiter and in late June, 20 Piscium does the same. From night to night you can easily watch the slow daily motion of Jupiter relative to 20 Piscium. The movement of Jupiter with respect to the stars is the result of the combined motion of Jupiter and Earth around the sun. Jupiter takes 11.9 years to complete one orbit of the sun.

Saturn shines at magnitude 0.5 and rises 90 minutes after Jupiter. June commences with Saturn lying 4° (eight moonwidths) west-southwest of Venus. On June 1 Venus rises at 3:22 a.m., just nine minutes after Saturn. Venus has just crossed into Aries, and Saturn remains in eastern Pisces for the month. The spectacular pair rapidly move apart as Venus chases the sun and Saturn lingers in its farther reaches of the solar system.

Daylight comes on quickly after these planets rise. Mars is lost in the sun's glare this month. Though early on June 22 you might catch the daylight occultation of Aldebaran by a very slim crescent moon. The moon rises an hour before the sun, but the occultation occurs about an hour after sunrise. Set your scope to track Aldebaran before sunrise if you can find it in the dawn's bright glow, then watch for the occultation shortly after 7 a.m. local time. ■

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

Early Bird Rewards



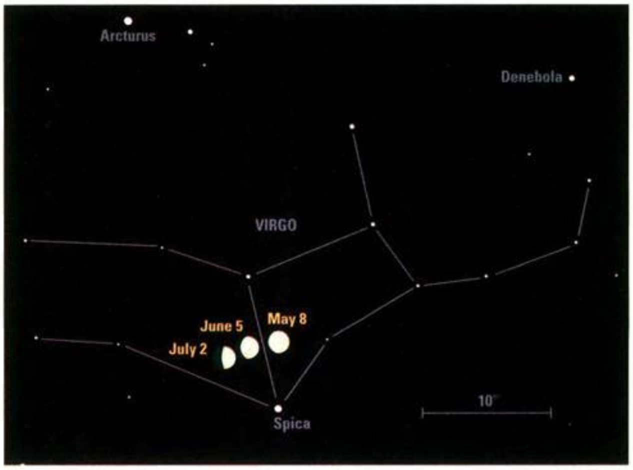
Winter's evening planet parade has given way to summer's morning line up. For many, the biggest difficulty to overcome is the time of day — getting up before 5 a.m. can prove to be quite a task.

Jupiter parades high in the southeast all month. On the morning of June 17, the last quarter moon joins the planet. It then slips nearly two lunar diameters south of Jupiter.

Next in line, though perhaps not as noticeable in the brightening dawn, is the planet Saturn. Saturn's rings are becoming more apparent, but it will be some time before the planet rises earlier than midnight.

The highlight of the month comes on June 21 when a slender crescent moon — most likely filled in with earthshine — slides a binocular field below dazzling Venus.

Which Lunar Month?



We are all familiar with the moon's 29.5-day period — just short of our calendar month — but have you seen its 27.3-day period? This is the moon's true orbital period (the time it takes the moon to make one complete orbit around Earth relative to the stars) — what we call a sidereal month.

If Earth did not move, the full moon to full moon period or synodic month (the time it takes the moon to make one orbit around Earth relative to the sun) would be 27.3 days. In reality, Earth has had time to pull the moon about one-twelfth of the way around the sun. For the moon to be back in line with the sun, it has to move one-twelfth of the way around its own orbit of Earth. One-twelfth of 27.3 days is 2.2 days, which is the difference between the sidereal month and synodic month.

This summer Spica can be our celestial reference point for the sidereal period. Every time the moon passes the star Spica, note its phase. It will be about two days less than what it was one month ago.

On June 5, the waxing gibbous — almost half way between first quarter and full — moon can be found near to Spica. By July 2, a first quarter moon floats above Spica.

With nothing more than your sight and a little cooperation from mother nature, you too can see that there's more to this phenomenon when it meets your eye.

David Hanon

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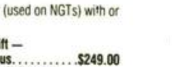

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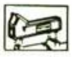

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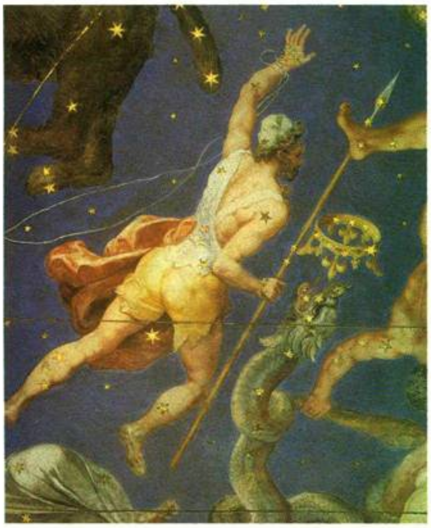

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Far away from the galactic plane, the Herdsman and the Northern Crown hold a modest flock of wondrous jewels.

by Tom Polakis

OUR CELESTIAL TOUR HAS taken us to the lair of the Great Bear Ursa Major and through the realm of galaxies in Virgo the Maiden. This month, we journey to the region in between. The area of the sky occupied by Bootes the Herdsman and his neighbor Corona Borealis the Northern Crown.

Both constellations are easily recognized. Bootes takes the form of a child's kite, with the 0.0-magnitude star Arcturus (Alpha [α] Bootis) marking the point where the kite's tail would be attached. Its neighbor, Corona Borealis, looks like a "U" or a crescent shaped crown, with the 2.2-magnitude star Alphecca (Alpha [α] Coronae Borealis) marking the crown's central jewel.

Arcturus is the fourth brightest star in the sky and the brightest star north of the celestial equator. It is a yellow K-type star whose hue is more golden-white and not as rich as its stellar cousins Aldebaran and Pollux. Arcturus is also a high-velocity star. Its apparent motion is roughly 2.3" per year to the south-southwest. In, 8000 years, Arcturus will have moved 5° or the distance between the pointer stars (Dubhe and Merak) in the cup of the Big Dipper.

The brightest star in Corona Borealis, brilliant white Alphecca, is an eclipsing binary some 75 light-years away. It shares the same motion in space as the Ursa Major Moving Group (see April 1998 *Astronomy*, page 69) and may be one of that band's far removed members.

The childhood saying, "take the arc to Arcturus then speed on to Spica," provides an easy starhop to Bootes and Corona Borealis. First seek out Ursa Major and its bright asterism the Big Dipper. Follow the arc made by the Dipper's handle, extending it past the star Alkaid to the south. Doing this leads you right to Arcturus and Bootes. The "U" of Corona Borealis can be found directly to the east of the Herdsman, near the upper portion of the kite. Continuing the arc of the handle southward past Arcturus brings you to the star Spica in Virgo.

When Bootes and Corona Borealis pass through the local meridian, they rest nearly overhead for observers at mid-northern latitudes. Though in a prime position for observing, this region of the sky lacks the number of objects normally found elsewhere. Only five galaxies and one globular cluster brighter than 12th magnitude may be found in Bootes and Corona Borealis.

We begin with the brightest galaxy in Bootes, **NGC 5248**. This galaxy has a bright core and surrounding haze that

NGC 5523

Tim Puckett

NGC 5466

Preston S. Justis

are faintly visible in a 7x50mm finderscope. At first glance, the sharp nuclear region pops into view. It is surrounded by a halo extending some 3' by 2' across. A 10-inch telescope and some patience reveal portions of the galaxy's spiral structure. The brightest parts of the spiral arms are due east and northwest of center. Between these subtle brightenings and the core are dark spaces delineating the arms.

A close inspection may unveil two other 15th-magnitude galaxies in the same 1° field with NGC 5248. This pair, UGC 8575 and UGC 8629, are believed to be satellite galaxies of the larger spiral. UGC 8575 can be found 27' west of NGC 5248, while UGC 8629 is separated from NGC 5248 by 30' in a position angle of 150°.

The interesting, low-density globular cluster **NGC 5466** is our next target. Its brightest stars shine at a magnitude of 14, so the cluster may appear as a cometary haze in telescopes with less than 6 inches of aperture. A 13-inch scope at a dark-sky site reveals a collection of 25 stars nestled in a soft background glow about 5' across. There is very little concentration toward the center, making this object appear more like a round open cluster than a globular.

BL Bootis, a star in the cluster's southeastern edge, varies in brightness between 14.4 and 15.1 magnitude over a period of 20 hours. This star is an anomalous Cepheid. Why anomalous? The star does not obey the typical period-luminosity relationship of Cepheid variables found in globulars.

Our next stop is **NGC 5523** just 1° east of 5th-magnitude 12 Bootis. This galaxy is inclined from edge-on by 17° and appears to have a slight brightening at the core. A 12th-magnitude star shines 2' northwest of the galaxy's edge.

Bootes is best known for its assortment of pretty double stars. **Epsilon** (ε) **Bootis** is a gem in excellent optics. The primary star is part of the constellation outline and is easily visible to the naked eye. At a magnification of 200x, the primary star appears yellowish with a 5th-magnitude secondary less than 3" to the northwest. The secondary star's color contrast to the bright primary gives the impression of being green.

The nearly edge-on galaxy, **NGC 5529**, may be a challenge to moderate scopes. Look 4° to the west-southwest of Gamma (γ) Bootis to find its thin streak. The galaxy appears to be a spindle-like 3' by 1' with a bright center in a 6-inch scope. A 20-inch telescope extends the long dimension to 5'.

The northern reaches of Bootes, near the handle of the Big Dipper, hold **NGC 5676**. This galaxy can easily be found in a 6-inch telescope at a dark site. Look for an oval glow elongated 3' by 1.5'. Around the bright stellar core is a round halo with "wings" that appear to extend the length of the galaxy.

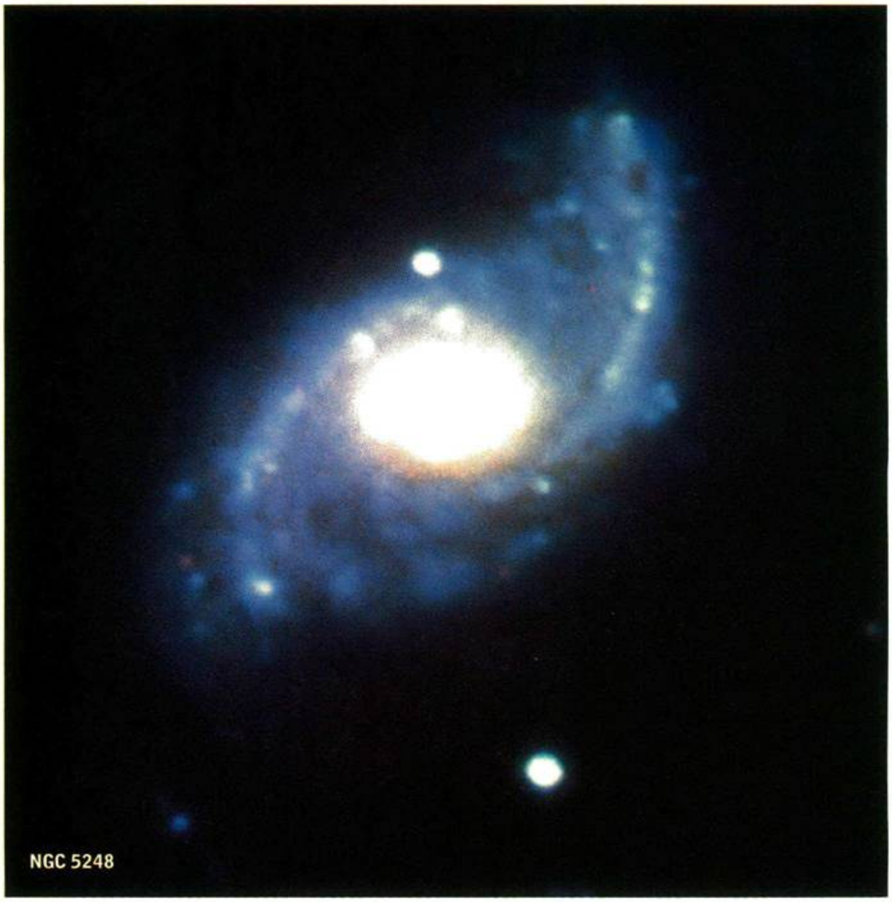
At a distance of 100 million light years, NGC 5676 is a foreground galaxy. It lies in the direction of the Bootes Void — a sphere roughly 250 million light-years across and nearly devoid of galaxies. The center of this sphere is about 700 million light-years away, and only a handful of galaxies have been found within its boundaries. The Bootes Void covers an area of sky about 20° in diameter.

44 Bootis is a binary star with an interesting orbit. From Earth, the orbit is viewed only 6° from being edge-on. The 6th-magnitude secondary is currently separated from the 5th-magnitude primary by just over 2". This gap will slowly widen over the next decade, but don't expect dramatic changes. The system's period of revolution is 225 years. 44 Bootis was first resolved in 1871, nearly one orbit ago, by Sir William Herschel. This double star is an easy split in a 6-inch telescope, with both stars displaying a yellowish tint.

The only deep-sky object of note in Corona Borealis is the dense galaxy cluster **Abell 2065**. It is a challenge for large scopes and can be located by forming a triangle with Alpha (α) and Beta (β) Coronae Borealis. Through a 20-inch telescope at high magnifications, seven galaxies can be seen in a 0.5° field. None of these are larger than 20" and all take great concentration to see. Abell 2065 holds more than 100 galaxies packed into this small field. It,

NGC 5529

Tim Puckett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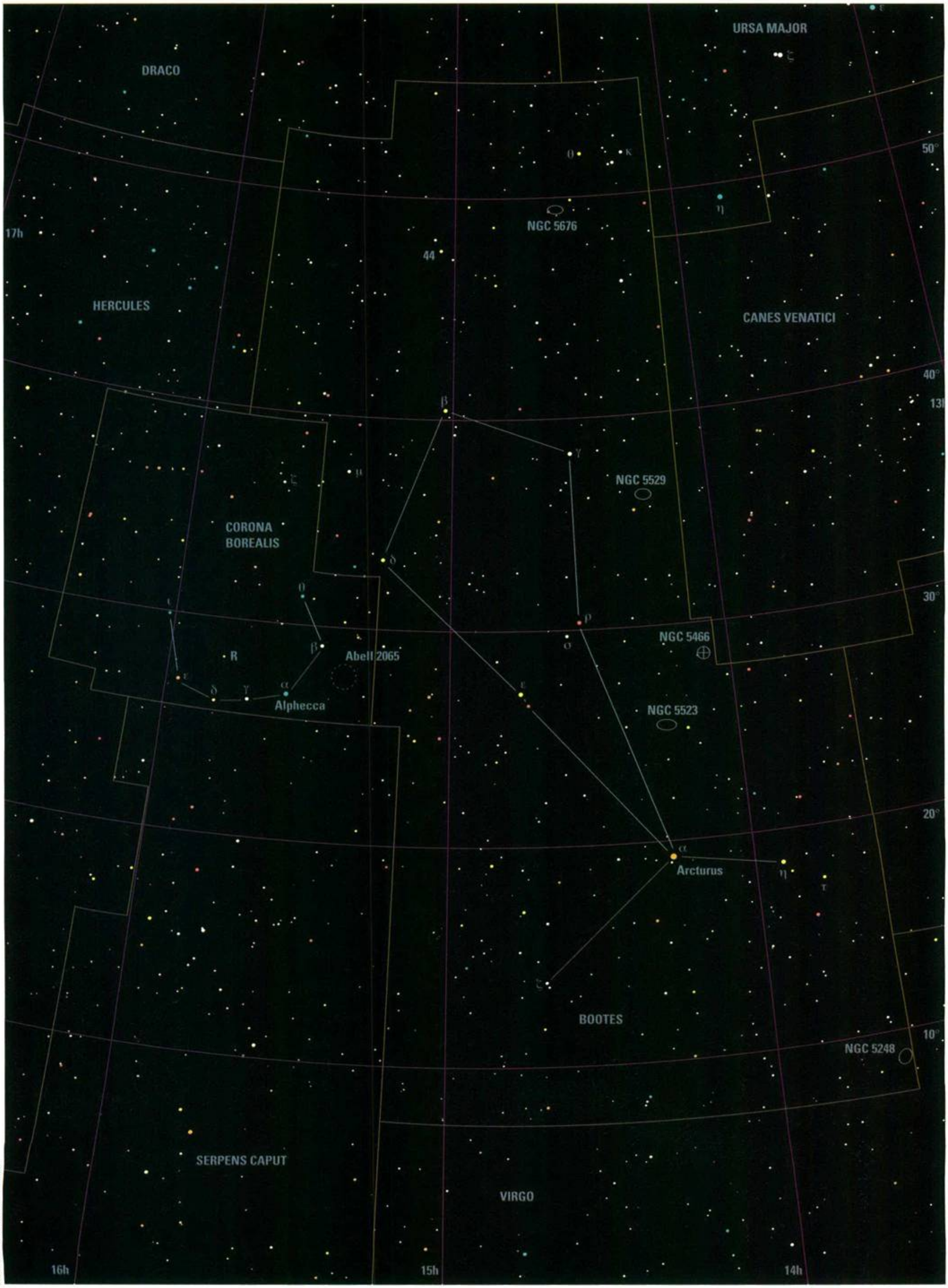
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Astronomy: Elisabeth Rowan

along with five other galaxy clusters at a similar distance (roughly 1 billion light-years), comprises the Corona Borealis Supercluster.

Near the center of the "U" of Corona Borealis is one of the sky's most interesting irregular variable stars, **R Coronae Borealis.** This star shines steadily at a magnitude of 6 before undergoing a rapid change in brightness. Its minima can vary between 10th to 15th magnitude and takes as little as several weeks to achieve — the period is similarly erratic. The most recent minimum occurred in October 1995. The star stayed near 14th magnitude for four months before recovering over a period of five months. These sporadic dimming episodes are thought to be the result of dust formation that occurs with pulses in the stellar atmosphere. Chances are, R Coronae Borealis will be its usual bright self when you look at it, but keep looking, since nobody knows when the next event will occur.

Zeta (ζ) Coronae Borealis is a pretty pair of 5th- and 6th-magnitude stars widely separated by 6". A small telescope will easily split the bluish-white twosome. You can find Zeta Coronae Borealis in the northwestern corner of the constellation, though it may be more easily found by hopping from Delta (δ) and Mu (μ) Bootis.

Tom Polakis is an aerospace engineer living in Arizona. His primary astronomical interests are deep-sky observation and photography.

The Keeper of the Bear

"Bootes only seem'd to roll
His Arctic charge around the Pole."
Hours of Idleness — Lord Byron (1788-1824)

Bootes is very near to the star Thuban (Alpha [α] Draconis), which, due to the procession of Earth's axis, was the pole star in the third millennium B. C. In 5700 B. C., the north celestial pole was very near to Beta (β) Bootis, the herdsman's head. That means Bootes was circumpolar and continually chasing Ursa Major ("His Arctic charge") around the pole. Bootes also helped to determine the seasons. The constellation was roughly aligned with the meridian at midnight on the summer solstice.

An interesting Native American myth of Bootes comes from the Micmac people who lived in the maritime provinces of Canada. The story of the *Never-Ending Bear Hunt* involves not only Bootes, but Corona Borealis and Ursa Major as well. The stars of Ursa Major (minus the three end stars of the Dipper's handle) are the Great Bear. Corona Borealis is the bear's den, while the bright stars of Bootes and the Dipper's handle are all hunters.

The story begins in late spring, when the hungry bear awakens from her winter sleep. As she leaves her den in search of food, the bear is spotted by the hunters. The hunters follow her through the sky chasing her all summer long. In autumn, the bear begins to prepare for her long winter hibernation. Her mind is occupied with other things, and that's when the hunters surprise her. As they kill the bear, her blood spills across the land coloring the trees with hues of red, giving them their autumn glory. All winter long the bear's skeleton lies on its back, but her spirit has fled to the den where another bear now rests. Next spring, this bear awakens and the never ending bear hunt starts all over again.

Another Native American legend comes from the Blackfoot. To them the stars of Corona Borealis mark the body of the Great Spider God. The Great Spider God watches over the world from her web (the constellation Hercules). When she wants to visit the land, she climbs down the Milky Way, conveniently located to the east of her web.

To the ancient Greeks and Romans, the stars of Corona Borealis marked the crown given to Princess Ariadne of Crete when she married Dionysus.

—Andrea Gianopoulos

Deep-Sky Objects in Bootes & Corona Borealis

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep./Per.	Type	Notes
NGC 5248	13h37.5m	08° 53'	10.3	6.2' x 4.6'	Gal	SAB(rs)bc
NGC 5466	14h05.5m	28° 32'	9.0	11.0'	Glob	
NGC 5523	14h14.8m	25° 19'	12.1	4.3' x 1.3'	Gal	SA(s)cd
NGC 5529	14h15.6m	36° 13'	11.9	5.7' x 0.7'	Gal	Sc
NGC 5676	14h32.8m	49° 28'	11.2	3.7' x 1.6'	Gal	SA(rs)bc
Epsilon Boo	14h45.0m	27° 04'	2.7, 5.1	2.8"	Dbl	Izar
44 Boo	15h03.8m	47° 39'	5.3, 6.2	2.1"	Dbl	I Bootis
Abell 2065	15h22.7m	27° 43'	-	30.5'	Gal Cl	109 galaxies
Zeta CrB	15h39.4m	36° 38'	5.1, 6.0	6.3"	Dbl	
R CrB	15h48.6m	28° 09'	5.7-14.8	Irreg.	VS	

Object: Designation in Messier, NGC, or other catalog. **R.A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./ Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Hubble type for galaxies or type for variable stars.

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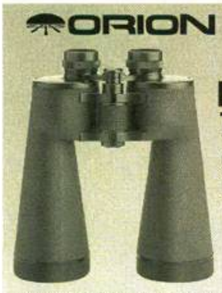

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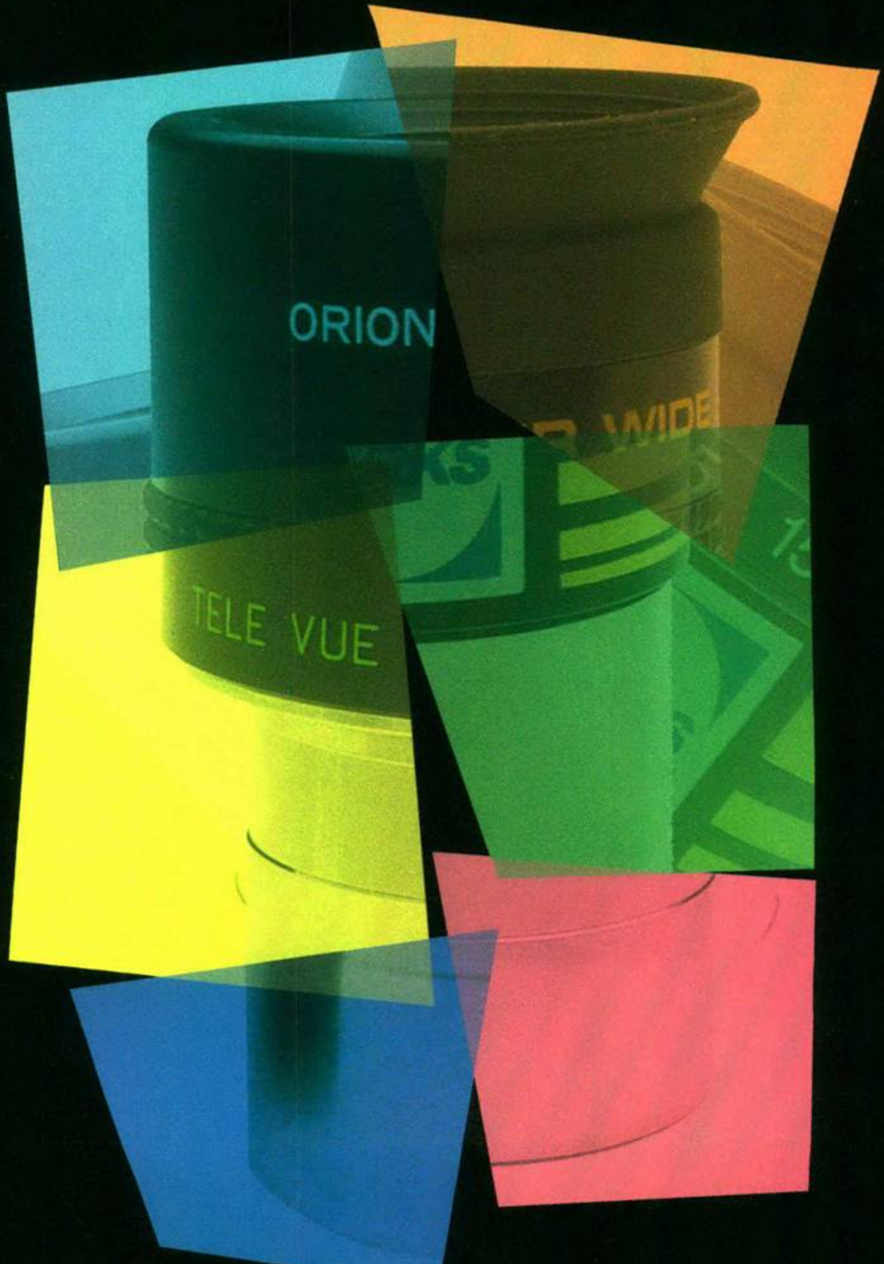
A cavalcade of eyepieces awaits today's consumer. We'll help you cut through the hype to get to the facts.

by Phil Harrington



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25mm

WHETHER YOU'VE JUST PURCHASED your first telescope or are a veteran observer, you certainly want to get the best views out of your instrument. While the optical quality of telescopes has been discussed and debated for years, comparatively little attention has been paid to choosing eyepieces. Eyepieces, after all, make up half of the optical system that delivers the image to an observer's eye.

Selecting the proper eyepieces for your telescope is just as critical as selecting the telescope itself. Without a quality eyepiece in place, even the finest instruments will produce mediocre views. Picking the right eyepiece(s) is one of the most difficult choices facing today's amateur astronomers.

EYE-BONICS

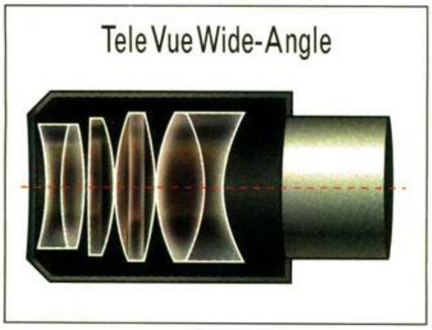
Department-store telescopes often refer to eyepieces by the magnification or "power" they produce. This is both misleading and inaccurate. Though a telescope's magnification is altered by changing the eyepiece, the magnification produced by any single eyepiece can vary greatly depending on the telescope it's used in.

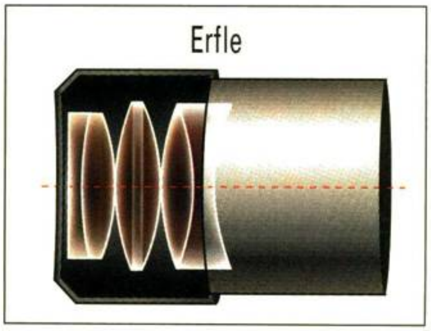
To calculate magnification, simply divide the telescope's focal length by the eyepiece's focal length. The focal length for a telescope is generally noted in the owner's manual, while an eyepiece usually has the number printed on it. Eyepiece focal lengths are given in millimeters (e.g. 25mm, 12mm, etc.), while telescope focal lengths are generally figured in inches. It's important to make sure that the units of measure match when doing your calculation. Let's use an 8-inch f/10 telescope and a 25mm eyepiece as an example. By multiplying the telescope's aperture (8) by it's focal ratio (10), we get a focal length of 80 inches, or 2032mm (25.4mm per inch). To find the magnification we divide 2032 by 25 and get 81x. That same eyepiece in a 6-inch f/8 telescope (focal length 1219mm) would yield 49x.

Many people think that higher magnification produces better views, but often nothing could be further from the truth. As magnification climbs, image quality often plummets quickly. Enlarging an image spreads its light out over a larger area. This causes the view to dim significantly, which makes focusing difficult if not impossible.

Just how much magnification is too much? If you own a smaller telescope (8 inches or less), obey the magnification speed limit: 60x per inch of aperture. For example, an 8-inch telescope can operate reasonably well at a maximum of 480x. Keep in mind that this value is not cast in stone. Your local atmospheric conditions and the instrument's quality also play a part. Given excellent optics, you may be able to go as high as 100x per inch on a good night, while the view may crumble at 30x per inch on other nights. A good rule of thumb, use only enough magnification to see the target. A small, sharp image is nicer than a big, blurry blob.

An important consideration when selecting an eyepiece is the size of its exit pupil. You can see the exit pupil of an eyepiece by putting it into the focusing mount and aiming the telescope at a bright surface, such as a wall or the daytime sky. Back away and look for the little disk of light that appears to float just behind the eye lens. To calculate the size of the exit pupil produced by an eyepiece in your telescope, divide the eyepiece's focal length by the telescope's focal ratio. An 8-inch f/10 telescope equipped with a 25mm eyepiece yields a 2.5mm exit pupil, while a 6-inch f/8 telescope and a 40mm eyepiece has a 5mm exit pupil.


Tele Vue Wide-Angle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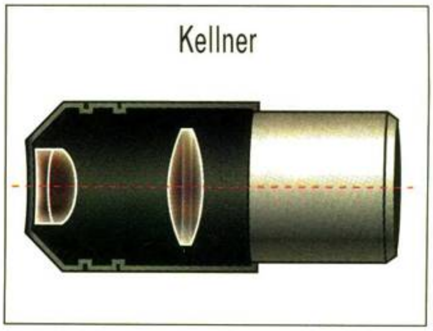
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Knowing the diameter of the exit pupil is important. If it's too large or too small the resulting image will likely prove unsatisfactory. Why? A fully dilated human pupil opens to about 7mm. This figure may vary from one person to another and shrinks as we age. If an eyepiece's exit pupil exceeds 7mm, then the eye will not be able to take in all of the light that the ocular has to offer. On the other hand, if the exit pupil is too small, then the image will be so dim that the target may be nearly impossible to see.

Just as there is no single best magnification for every object, neither is there one best exit pupil. It depends on what you are trying to observe.

Although magnification gives some feel for how large a chunk of sky will fit within an eyepiece's view, it can only be precisely figured by knowing another factor: the apparent field of view. This refers to the eyepiece field's edge-to-edge angular diameter (expressed in degrees) as seen by the observer's eye. To understand this, try peering through a long, thin tube, such as an empty roll of paper towels. You will see a very narrow view of the world. This perceived angle of coverage is known as the apparent field of view.

The apparent fields of most eyepieces range from a cramped 30° to more than 80°. In general, select eyepieces with at least a 45° apparent field because of the exaggerated tunnel-vision effect through anything less. An apparent field of 60° or greater gives the illusion of staring out the porthole of an imaginary spaceship, an impressive effect.

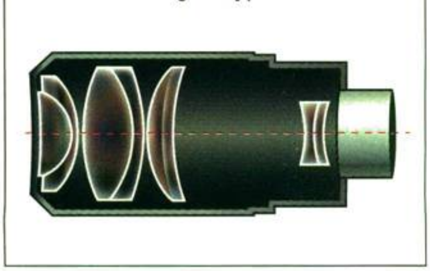
The amount of sky that will squeeze into an eyepiece is called its true or real field of view and is determined by dividing the apparent field by the magnification. An 8-inch f/10 telescope and a 25mm eyepiece produce 81x and a 2.5mm exit pupil. Suppose this particular eyepiece is advertised as having a 40° apparent field. Dividing 40/81 shows that this eyepiece produces a true field of approximately 0.5°, just large enough to fit the full moon.

Another term often encountered in eyepiece literature but rarely defined is parfocal. Parfocal means that the telescope will not require refocusing when switching from one eyepiece to another, a real convenience. Keep in mind, however, that just because an eyepiece is claimed to be parfocal, it is not universally parfocal. In other words, it does not focus at the same distance as all other parfocal eyepieces. If two eyepieces of the same optical design, say a 26mm Plössl from one manufacturer and a 12mm Plössl from another, each claim to be parfocal, they are most likely parfocal with other eyepieces in the manufacture's line, but not with each other. At the same time, two different eyepiece designs sold by the same company and declared parfocal, are probably not parfocal with each other.

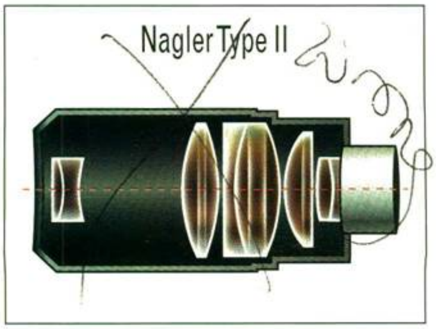
A well-designed eyepiece will also have good eye relief. Eye relief is the distance from the eye lens to the observer's eye where the entire field of view is seen at once. Less expensive eyepieces may offer eye relief only one-quarter their focal length, which is much too close for comfortable viewing. Some modern designs offer an eye relief of 20mm regardless of the eyepiece's focal length, making observing more enjoyable, especially for those who must wear eyeglasses. Of course, there can also be too much of a good thing. Excessive eye relief can make it difficult for the observer to hold his or her head steadily while hovering above the eyepiece.

High-quality eyepieces also feature fully coated lenses. Here, a thin layer of magnesium fluoride antireflection coating is deposited on each optical surface to increase light transmission and decrease unwanted reflections and ghost images. Better still are fully multicoated lenses, where the optical coatings have been applied in several microscopically thin layers. Single-coated lenses have a bluish or purplish tint, while multicoated lenses show tinges of green, red, or purple.

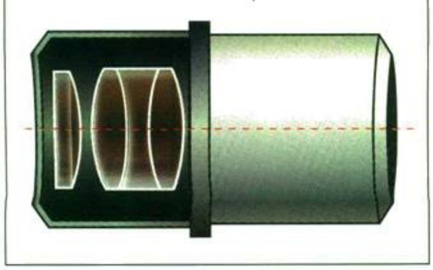
Nagler Type I



Nagler Type II



Orthoscopic



Finally, a high-quality eyepiece should be threaded for both light pollution reduction (LPR or nebula) filters and color filters. Some manufacturers use threads designed to accept only their own filters, but most companies use standardized threads so that filters from different manufacturers will screw into the eyepiece barrel. Better eyepieces also come with rubber eyeguards. These serve to block stray light from sneaking around the corner of your eye and are a must if you observe from urban or suburban locales. Aftermarket eyeguards can be added easily to most eyepieces that do not come with them factory installed.

EYEPIECE EVALUATION

The least expensive eyepiece design that is capable of delivering acceptable performance is the Kellner. Some manufacturers may call them Modified Achromats (MA) or Super Modified Achromats (SMA), but all are essentially the same. Invented in 1849 by Carl Kellner, these eyepieces use a single-element field lens and a two-element achromatic eye lens. Edmund Scientific offers a "backwards Kellner" called the RKE, which flips the design by using a two-element field lens and a single-element eye lens. Kellners and RKEs feature fairly good color correction and edge sharpness and have apparent fields of view ranging between 40° and 5°.

A long-time favorite of many amateur astronomers is the orthoscopic, or Abbe, eyepiece. Introduced in 1880 by Ernst Abbe, the orthoscopic consists of a cemented triple field lens matched to a single-element eye lens. Color transmission and contrast are superb, especially when combined with modern optical coatings. Orthoscopic eyepieces remain one of the best eyepieces for nearly all amateur telescopes. They yield equal or higher image contrast than many of the

Eyepiece Terminology

Aperture: The diameter of the primary lens or mirror of a telescope.

Focal Length: The distance from a lens or mirror to the point where light converged by it comes to a focus. For eyepieces, it is expressed in millimeters.

Focal Ratio (the f/number): The ratio of the focal length of a lens or mirror to its aperture (denoted as f/10, f/5, etc.)

Coatings: The optical coatings applied to the eyepiece's elements. C = coated, a single-layer of magnesium fluoride, generally only on the outer surfaces of the eye and field lenses; FC = fully coated, single coating on all optical surfaces; MC = multicoated, multiple coatings on some optical surfaces; FMC = fully multicoated, multiple coatings on all optical surfaces.

Exit Pupil: The exit pupil is the diameter of the beam of light leaving the eyepiece and traveling to the observer's pupil.

Eye Lens: The individual lens element(s) closest to the observer's eye.

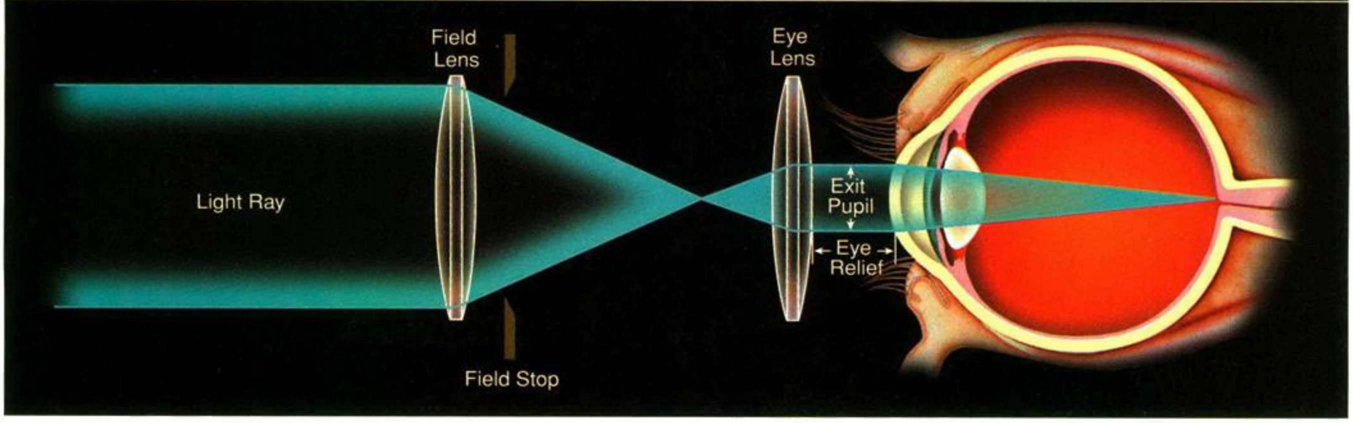
Eye Relief: The distance, in millimeters, that an observer's eye must be away from the eye lens in order to see the entire field transmitted by the eyepiece.

Eye Cups: Useful for preventing stray light from entering through the corner of the observer's eye.

Field Lens: The lens element(s) farthest from the observer's eye, the one facing inward toward the telescope.

Field Stop: The element limiting the size or angular breadth of the object that can be imaged by the system. It is usually mounted just beyond the field lens at the focus of the eyepiece, giving a sharp edge to the field of view.

Parfocal: The eyepiece focuses at nearly the same distance as other eyepieces in the manufacturer's series. Occasionally, some eyepieces in a particular line may not be parfocal with all others in the same line, but instead, only with one or two others.



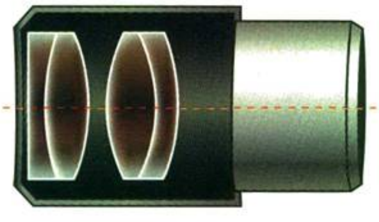
new-generation "super eyepieces," especially on planets. Sadly, few companies still sell orthoscopics; instead, many recommend the Plössl eyepiece.

Indeed, the Plössl is one of the most highly regarded eyepieces among today's amateur astronomers. Its twin close-set pairs of doublet lenses for the eye lens and the field lens combine into an excellent ocular that is very nearly comparable to the orthoscopic in terms of color correction and definition but with better eye relief and a larger apparent field of view. Developed in 1860 by G. S. Plössl, an optician living in Vienna, Austria, the Plössl took more than a century to catch on among amateur astronomers, but now, it is perhaps today's most popular design. All of the Plössls sold today are quite good, but some are perceptibly better than others. I prefer not to generalize, but in this case, you pretty much get what you pay for. The more expensive Plössls typically maintain closer optical and mechanical tolerances, feature multicoated optics, and have blackened lens edges and threads to suppress stray light.

Meade's Series 4000 Super Plössls are also good performers, with very good image sharpness across the field. Technically, they are not conventional Plössls, but rather a four-element, hybrid design. Celestron Ultima eyepieces, manufactured by Vixen Optical Company of Japan, are also knock-offs of the Plössl design. Depending on focal length, each incorporates between four and seven optical elements to create fields between a slim 36° to a more acceptable 51° in shorter focal length versions. Finally, Orion Ultrascopic eyepieces are also hybrid designs that produce good images and relatively wide, 52° apparent fields.

Takahashi LE and Vixen Lanthanum LV eyepieces are both company-proprietary designs that offer very good image quality and contrast. Eyeglass

Plössl



Manufacturer	Design	Focal Length	Apparent FOV (°)	Coatings	Eye Relief (mm)	Eye Cups	Parfocal	Price
0.965-INCH BARREL								
Celestron	SMA	25	52	C	n/s	No	n/s	$35
	SMA	12	52	C	n/s	No	n/s	$35
	SMA	10	52	C	n/s	No	n/s	$35
	SMA	6	52	C	n/s	No	n/s	$35
	Plössl	26	52	MC	22	No	n/s	$45
	Plössl	17	52	MC	13	No	n/s	$45
	Plössl	12.5	52	MC	8	No	n/s	$45
	Plössl	10	52	MC	7	No	n/s	$45
	Plössl	7.5	52	MC	5	No	n/s	$45
	Plössl	6.3	52	MC	5	No	n/s	$45
Meade	MA	40	36	C	18	No	No	$34
	MA	25	40	C	16	No	No	$34
	MA	12	40	C	8	No	No	$34
	MA	9	40	C	6	No	No	$34
Orion	Explorer II	25	50	FC	15	No	Yes	$30
	Explorer II	17	50	FC	11	No	Yes	$30
	Explorer II	13	50	FC	7	No	Yes	$30
	Explorer II	10	50	FC	4	No	Yes	$30
	Explorer II	6	50	FC	3	No	Yes	$30
	Plössl	26	50	FC	16	Yes	Yes	$50
	Plössl	20	50	FC	13	Yes	Yes	$50
	Plössl	17	50	FC	10	Yes	Yes	$50
	Plössl	12.5	50	FC	8	Yes	Yes	$50
	Plössl	10	50	FC	5	Yes	Yes	$50
	Plössl	7.5	50	FC	4	Yes	Yes	$50
1.25-INCH BARREL								
Adorama	Plössl	40	43	FC	31	No	Yes	$55
	Plössl	32	50	FC	22	No	Yes	$55
	Plössl	25	50	FC	22	No	Yes	$40
	Plössl	20	50	FC	n/s	No	Yes	$40
	Plössl	17	50	FC	13	No	Yes	$40
	Plössl	12.5	50	FC	8	No	Yes	$50
	Plössl	10	50	FC	6.5	No	Yes	$40
	Plössl	7.5	50	FC	5	No	Yes	$40
	Plössl	6.3	50	FC	5	No	Yes	$50
Celestron	SMA	25	52	C	n/s	No	n/s	$35
	SMA	12	52	C	n/s	No	n/s	$35
	SMA	10	52	C	n/s	No	n/s	$35
	SMA	6	52	C	n/s	No	n/s	$35
	Plössl	40	46	MC	31	No	n/s	$60
	Plössl	32	50	MC	22	No	n/s	$60
	Plössl	26	52	MC	22	No	n/s	$45
	Plössl	20	50	MC	20	No	n/s	$45
	Plössl	17	52	MC	13	No	n/s	$45
	Plössl	12.5	52	MC	8	No	n/s	$45
	Plössl	10	52	MC	7	No	n/s	$45
	Plössl	7.5	52	MC	5	No	n/s	$45
	Plössl	6.3	52	MC	5	No	n/s	$45
	Ultima	42	36	FMC	32	Yes	No	$120
	Ultima	35	49	FMC	25	Yes	No	$120
	Ultima	30	50	FMC	21	Yes	Yes	$100
	Ultima	24	51	FMC	18	Yes	Yes	$100
	Ultima	18	51	FMC	13	Yes	Yes	$100
	Ultima	12.5	51	FMC	9	Yes	Yes	$85
	Ultima	7.5	51	FMC	5	Yes	Yes	$85
	Ultima	5	50	FMC	4	Yes	Yes	$85
Edmund	RKE	28	45	C	25	Yes	Yes	$50
	RKE	21	45	C	19	No	Yes	$50
	RKE	15	45	C	13	No	Yes	$50
	RKE	12	45	C	11	No	Yes	$50
	RKE	8	45	C	8	No	Yes	$50
Meade	MA	40	36	MC	18	No	No	$38
	MA	25	40	MC	16	No	No	$38
	MA	12	40	MC	8	No	No	$38
	MA	9	40	MC	6	No	No	$38
	Plössl	40	44	MC	29	Yes	No	$80

Manufacturer	Design	Focal Length	Apparent FOV (°)	Coatings	Eye Relief (mm)	Eye Cups	Parfocal	Price
	Plössl	25	50	MC	16	Yes	Yes	$50
	Plössl	16	50	MC	10	Yes	Yes	$50
	Plössl	9.5	50	MC	6	Yes	Yes	$50
	Plössl	6.7	50	MC	4	Yes	Yes	$50
	Plössl	5	50	MC	3	Yes	Yes	$50
	Super Plössl	40	44	MC	30	Yes	No	$100
	Super Plössl	32	52	MC	20	Yes	Yes	$100
	Super Plössl	26	52	MC	18	Yes	Yes	$80
	Super Plössl	20	52	MC	13	Yes	Yes	$80
	Super Plössl	15	52	MC	9	Yes	Yes	$80
	Super Plössl	12.4	52	MC	7	Yes	Yes	$80
	Super Plössl	9.7	52	MC	5	Yes	Yes	$80
	Super Plössl	6.4	52	MC	3	Yes	Yes	$80
	Super Wide Angle	24.5	67	MC	19	Yes	Yes	$180
	Super Wide Angle	18	67	MC	14	Yes	Yes	$150
	Super Wide Angle	13.8	67	MC	10	Yes	Yes	$140
	Ultra Wide Angle	6.7	84	MC	11	Yes	Yes	$200
	Ultra Wide Angle	4.7	84	MC	7	Yes	Yes	$170
Orion	Explorer II	25	50	FC	15.5	No	Yes	$30
	Explorer II	17	50	FC	12	No	Yes	$30
	Explorer II	13	50	FC	7	No	Yes	$30
	Explorer II	10	50	FC	5	No	Yes	$30
	Explorer II	6	50	FC	4	No	Yes	$30
	Plössl	40	43	FC	22	Yes	No	$60
	Plössl	32	50	FC	25	Yes	Yes	$60
	Plössl	26	50	FC	18	Yes	Yes	$50
	Plössl	20	50	FC	14	Yes	Yes	$50
	Plössl	17	50	FC	13	Yes	Yes	$50
	Plössl	12.5	50	FC	7	Yes	Yes	$50
	Plössl	10	50	FC	7	Yes	Yes	$50
	Plössl	7.5	50	FC	5	Yes	Yes	$50
	Ultrascopic	35	49	FMC	24.8	Yes	No	$140
	Ultrascopic	30	52	FMC	20.5	Yes	Yes	$120
	Ultrascopic	25	52	FMC	16.6	Yes	Yes	$90
	Ultrascopic	20	52	FMC	13.1	Yes	Yes	$80
	Ultrascopic	15	52	FMC	9.8	Yes	Yes	$80
	Ultrascopic	10	52	FMC	6.1	Yes	Yes	$80
	Ultrascopic	7.5	52	FMC	5.3	Yes	Yes	$80
	Ultrascopic	5	52	FMC	6.1	Yes	Yes	$90
	Ultrascopic	3.8	52	FMC	5.3	Yes	Yes	$90
Parks	Kellner	25	40	MC	15	No	Yes	$45
	Kellner	12	40	MC	8	No	Yes	$45
	Kellner	6	40	MC	5	No	Yes	$45
	Plössl	35	49	FMC	34	Yes	No	$175
	Plössl	30	52	FMC	30	Yes	Yes	$140
	Plössl	25	52	FMC	24	Yes	Yes	$105
	Plössl	20	52	FMC	19	Yes	Yes	$105
	Plössl	15	52	FMC	14	Yes	Yes	$100
	Plössl	10	52	FMC	10	Yes	Yes	$100
	Plössl	7.5	52	FMC	9	Yes	Yes	$100
	Plössl	5	52	FMC	10	Yes	Yes	$170
	Plössl	3.8	52	FMC	8	Yes	Yes	$170
Pentax	XL	28	55	FMC	20	Yes	Yes	$300
	XL	21	65	FMC	20	Yes	Yes	$310
	XL	14	65	FMC	20	Yes	Yes	$310
	XL	10.5	65	FMC	20	Yes	Yes	$310
	XL	7	65	FMC	20	Yes	Yes	$320
	XL	5.2	65	FMC	20	Yes	Yes	$320
Takahashi	LE	30	52	FMC	20	Yes	Yes	$205
	LE	24	52	FMC	17	Yes	Yes	$180
	LE	18	52	FMC	13	Yes	Yes	$180
	LE	12.5	52	FMC	9	Yes	Yes	$180
	LE	7.5	52	FMC	10	Yes	Yes	$190
	LE	5	52	FMC	10	Yes	Yes	$190
Tele Vue	Nagler	7	82	FMC	10	Yes	Yes	$230
	Nagler	4.8	82	FMC	7	Yes	Yes	$190
	Panoptic	19	68	FMC	13	Yes	Yes	$250
	Panoptic	15	68	FMC	10	Yes	Yes	$225
	Plössl	40	43	FMC	28	Yes	No	$125
	Plössl	32	50	FMC	22	Yes	Yes	$120

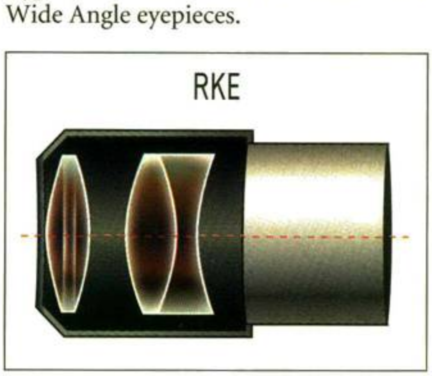
wearers will find the Lanthanum LVs especially interesting, as all offer an exceptionally long 20mm eye relief regardless of focal length. This lets the observer stand back from the eyepiece and still take in the whole scene.

"Super Eyepieces," with their extremely wide fields of view, advanced optical designs, and near-perfect image correction, represent the fastest-changing segment of the eyepiece market today.

The first super eyepiece was the Erfle, born from military applications in World War I. While offering comparatively wide views of the sky, the Erfle suffers inordinately from optical faults, especially curvature near the edge of field, and so has been overshadowed by other eyepieces. Another early design, the König, still enjoys some popularity, but again, cannot match the sharpness offered by orthoscopics, Plössls, or the newer super eyepieces described below.

Modern super eyepieces can be further divided into two groups based on their apparent fields of view: wide-field and extra-wide field. Wide-field eyepieces are built around complex assemblies that house anywhere between five and eight glass elements set in several lens groups. All enjoy apparent fields that range between 60° and 70° with excellent image sharpness and contrast. Included in this eyepiece family are the Pentax XL, Meade Super Wide Angle, and Tele Vue Panoptic.

Extra-wide eyepieces deliver tack-sharp images that are unspoiled by internal reflections, astigmatism, and just about every other known optical aberration. But wait, there's more. Not only do they do all of that exceptionally well, they do it across incredible apparent fields measuring more than 80°. These "big kids on the block" include Tele Vue Nagler and Nagler Type II oculars, as well as Meade Ultra Wide Angle eyepieces.



THE BOTTOM LINE

Okay, you're convinced that you want to buy a new eyepiece or two, but which should you buy for your telescope? Does everyone have to run out and buy a set of super eyepieces? No. While these giants are terrific, especially in "fast" telescopes, many hours of great enjoyment can still be yours with far less costly eyepieces. Indeed, most telescopes are better off with smaller, lighter, more conventional eyepieces.

A good place to begin is with a basic set of three eyepieces plus a high-quality, fully multicoated Barlow lens. Your core set should consist of a 25 to 30mm eyepiece for low power, a 12 to 14mm eyepiece for medium power, and a 7 to 9mm eyepiece for high power. Try to space the eyepieces to avoid focal-length duplication. If you own a 25mm eyepiece and a 2x Barlow lens, don't buy a 12mm eyepiece; instead, consider a 10mm or 14mm.

Once you have a core set, expand the range of available focal lengths. If you own an f/10 or slower telescope, consider an eyepiece between 40mm and 55mm focal length. These will give spectacular views of large deep-sky objects that might otherwise go unappreciated. If your observing site enjoys steady seeing conditions, then a very short focal length eyepiece between 2.5mm and 6mm will deliver outstanding views of the moon and planets.

Nothing will pump life into a telescope more than a good set of eyepieces. Begin with a team of three, and before you know it, you'll be armed to the hilt with a dozen or more of every type and focal length. Of course, then another problem surfaces: Which eyepiece storage case is best? But that will have to wait for another day. ■

Phil Harrington is the author of five books, including Star Ware: The Amateur Astronomer's Ultimate Guide to Choosing, Buying, and Using Telescopes and Accessories. *Visit his home page at http://ourworld.compuserve.com/homepages/pharrington/.*

Note: All technical specifications were supplied by the *manufacturers* and have not been independently verified. Prices reflect the typical price one might expect to pay, as of early 1998. All prices are subject to change and may vary from one retailer to another.

Manufacturer	Design	Focal Length	Apparent FOV (°)	Coatings	Eye Relief (mm)	Eye Cups	Parfocal	Price
	Plössl	25	50	FMC	17	Yes	Yes	$100
	Plössl	20	50	FMC	14	Yes	Yes	$100
	Plössl	15	50	FMC	10	Yes	Yes	$90
	Plössl	11	50	FMC	8	Yes	Yes	$90
	Plössl	8	50	FMC	6	Yes	Yes	$90
University	Kellner	20	40	FC	n/s	No	No	$36
	Kellner	12	40	FC	n/s	No	No	$36
	Kellner	9	40	FC	n/s	No	No	$36
	König II	32	52	FMC	n/s	No	No	$115
	König II	24	60	FMC	n/s	No	No	100
	König II	16	65	FMC	n/s	No	No	$80
	König II	12	60	FMC	n/s	No	No	$80
	Orthoscopic	25	42	MC	n/s	No	No	$55
	Orthoscopic	18	42	MC	n/s	No	No	$55
	Orthoscopic	12.5	42	MC	n/s	No	No	$55
	Orthoscopic	9	42	MC	n/s	No	No	$55
	Orthoscopic	7	42	MC	n/s	No	No	$55
	Orthoscopic	5	42	MC	n/s	No	No	$55
	Plössl	12	60	MC	n/s	No	No	$60
Vernonscope	Brandon	32	50	FC	26	Yes	Yes	$165
	Brandon	24	50	FC	19	Yes	Yes	$165
	Brandon	16	50	FC	13	Yes	Yes	$165
	Brandon	12	50	FC	10	Yes	Yes	$165
	Brandon	8	50	FC	6	Yes	Yes	$165
Vixen	Lanthanum LV	15	50	FMC	20	Yes	Yes	$140
	Lanthanum LV	12	50	FMC	20	Yes	Yes	$135
	Lanthanum LV	10	50	FMC	20	Yes	Yes	$135
	Lanthanum LV	9	50	FMC	20	Yes	Yes	$140
	Lanthanum LV	6	45	FMC	20	Yes	Yes	$135
	Lanthanum LV	5	45	FMC	20	Yes	Yes	$140
	Lanthanum LV	4	45	FMC	20	Yes	Yes	$150
	Lanthanum LV	2.5	45	FMC	20	Yes	Yes	$150
1.25/2-INCH BARREL								
Meade	Ultra Wide Angle	14	84	MC	23	Yes	No	$300
	Ultra Wide Angle	8.8	84	MC	16	Yes	Yes	$240
Tele Vue	Panoptic	22	68	FMC	15	Yes	Yes	$290
	Nagler Type 2	16	82	FMC	10	Yes	Yes	$330
	Nagler	13	82	FMC	18	Yes	Yes	$330
	Nagler Type 2	12	82	FMC	11	Yes	Yes	$300
	Nagler	9	82	FMC	12	Yes	Yes	$230
2-INCH BARREL								
Meade	Super Plössl	56	52	MC	47	Yes	No	$200
	Super Wide Angle	40	67	MC	27	Yes	No	$300
	Super Wide Angle	32	67	MC	20	Yes	No	$240
Orion	Plössl	50	50	MC	42	No	No	$100
Parks	Plössl	50	50	FMC	38	No	No	$140
Pentax	XL	40	65	FMC	20	Yes	Yes	$320
Takahashi	LE	50	50	FMC	n/s	Yes	No	$380
Tele Vue	Nagler Type 2	20	82	FMC	12	Yes	Yes	$430
	Panoptic	35	68	FMC	24	Yes	Yes	$370
	Panoptic	27	68	FMC	19	Yes	Yes	$340
	Plössl	55	50	FMC	38	Yes	No	$250
University	König	40	70	MC	n/s	No	No	$196
	König	32	60	FMC	n/s	No	No	$130
	König	25	70	MC	n/s	No	No	80
	Plössl	55	50	MC	n/s	No	No	$120
Vernonscope	Brandon	48	50	FC	38	Yes	Yes	$295
Vixen	Lanthanum LV	30	60	FMC	20	Yes	Yes	$180

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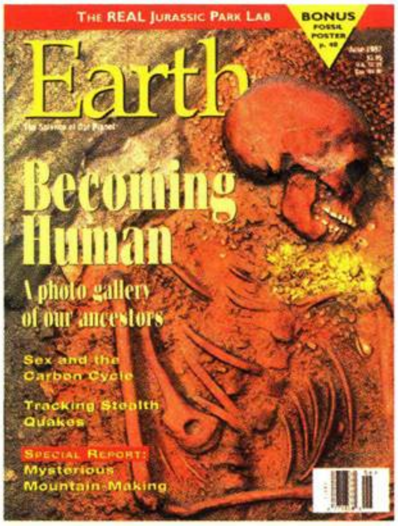
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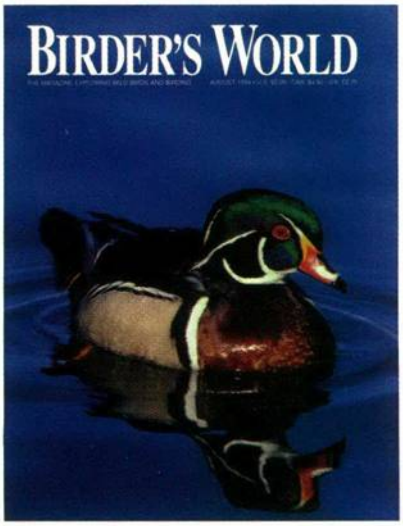

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Amateur astronomers John Cordiale and Jim Barot, Jr. wanted to share their interest with a lot of people, but without a lot of hassle. "We found video imaging to be the easiest," Jim says. "You don't have to be a professional astronomer or have a computer—you just need your telescope, a TV, and an Astrovid CCD (charge-coupled device) video system."

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2'' adapter for C-8, Meade 2080, etc.	$29.50
2'' adapter for C-80, C-100 refractor	$39.50
2'' adapter for C-70, C-80F, C-100F fluorite	$39.50
2'' adapter for C-6, Comet Catcher, Meade 312	$30.00

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1'' long 1¼'' OD thread-in extension	12.00
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4½'' long extension for 1¼'' eyepieces	$29.00
3'' long extension for 2'' eyepieces*	$29.00
2'' long extension for 2'' eyepieces*	$29.00

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2''/1¼'' reducing bushing, threaded 48mm*	$25.00
2''/T-thread adapter, threaded 48mm*	$25.00
T-thread/1¼'' adapter	$25.00
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Low profile star diagonal eyepiece holder	$16.00
Meade 2'' Diagonal/Giant Easy-Guider	$39.50

**Threaded to hold 48mm filters.*

LED FLASHLIGHT . $14.95

LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. Uses 2 AA cells (incl.) which last 60-100 hours.

LUMILITE red LED flashlight	**$14.95**
STARLITE™ adj. red LED flashlight	**$24.95**

RICH FIELD! 2° in 8'' SCT

NOW ONLY
$99.95

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	**$99.95**
Giant Rich-Field Viewer (10-14'')	**$250.00**

Optional Eyepiece	**TRUE FIELD**	**Price**
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2'' Wide-Field†	1.9°	**add $429**
Meade 40mm 2'' Wide-Field†	2.4°	**add $489**

†Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

PENTAX 65° XL EYEPIECES

AMAZING performance! **All have** 20mm eye relief, adjustable helical eye guard, super multicoatings, **E.D. glass**.

5.2mm F.L., 65° Apparent Field 1¼''	**$279**
7mm F.L., 65° Apparent Field 1¼''	**$279**
10.5mm F.L., 65° Apparent Field 1¼''	**$269**
14mm F.L., 65° Apparent Field 1¼''	**$269**
21mm F.L., 65° Apparent Field 1¼''	**$269**
28mm F.L., 55° Apparent Field 1¼''	**$259**
40mm F.L., 65° Apparent Field 2''	**$299**

MEADE 7'' - 16'' LX200 *NEW! 7'' - 10'' LX50*

8'' LX50
$1395

16'' LX200 $14,950

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller.
LX200 - full computer control w/64K obj. mem.
Tripod: extra for LX50; included for LX200
NOTE: A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200.

NEW! 3.5'' f/14 ETX Maksutov ($20)	**$595**
ETX, showroom price *(no 8 month wait)*	**$649**
8'' LX10 w/wedge, hand controller ($65)	**$995**
Field Tripod for 8'' LX10 ($20 P&S)	**$195**
8'' LX50 w/wedge ($115 P&S)	**$1395**
Adj. tripod for 8-10'' SCT ($30 P&S)	**$295**
8'' LX200 w/computer ($65 P&S)	**$2795**
Wedge for photographing w/8'' LX200	**$139**
7'' LX50 f/15 Maksutov w/wedge ($125 P&S)	**$1795**
10'' LX50, f/10 w/wedge, dec. motor, hand controller ($155 P&S)	**$1695**
10'' LX200 w/computer ($155 P&S)	**$3195**
12'' LX200 (f/10 only)($215 P&S)	**$4495**
Super Wedge for photogr. w/10'',12'' LX200	**$395**
16'' LX200 f/10 w/tripod ($385 P&S)	**$14,950**
Dew Shields: 8'' .... **$119**; 10''	**$129**
12'' .... **$189**; 16''	**$289**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4''—8'', f/6 or f/10	**$249**
Giant EASY-GUIDER for 10''/12'' f/4-f/10	**$395**

MEADE STARFINDERS

8'' f/6
$749

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6'' f/8 Dobsonian Starfinder ($46 P&S)	**$349**
6'' f/8 Equat. Starfinder 6(add $79 P&S)	**$649**
8'' f/6 Dobsonian Starfinder (add $59 P&S)	**$449**
8'' f/6 Equat. Starfinder 8 (add $89 P&S)	**$749**
10'' f/4.5 Dobsonian Starfinder ($85 P&S)	**$599**
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$879**
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$895**
16'' f/4.5 Dobsonian Starfinder (freight COD)	**$1195**
16'' f/4.5 Starfinder 16 (ship. freight COD)	**$2695**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

Magellan computer; specify Dob. or Eq. ($15 ship)	**$295**
LUMICON 1¼'' UHC or O-III Filter	**$99.50**

Vinyl covers to keep dust-free (2 req.) for 6'' - **$10**; for 8'' - **$15**; for 10'' - **$20**; for 16'' - **$35**

SKY VECTOR™ $299!!

Includes Computer, Encoders, Hardware

LOW PRICE—from $299

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $299

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349

Over 3600 objects! — Also includes planets and full visual descriptions.

NGC SKY VECTOR™ $439

12,000 Objects!— PC Serial Port

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LUMICON

NGC SKY VECTOR with IDENTIFY (Sky Tour) mode, 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16'' Dobsonian.
Ultima 8, 9¼, 11 **add $25**, C-14 **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7	**$129.00**
2'' Adapter for Hasselblad	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow) **$259.00**

LUMICON ACCESSORIES

LUMICON, Livermore, CA 94550 (925) 447-9570 FAX (925) 447-9589

LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$199.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 4''—8''	**$39.00**
UV/Dust Seal (lg.) for Meade 10''—12''	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

LOW PROFILE FOCUSERS New! Thread-on for Odyssey

FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape!
Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
LUMICON 2'' Helical Focuser 1½'' high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$189.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, 45°version	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER	**$199.50**
1¼'' right-angle 80mm SUPER-FINDER	**$209.50**
1¼'' right-angle version, w/star diagonal	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$59.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$49.00**

PROTECTIVE DUST COVERS

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser **4/$2**

2'' O.D. plug	**2/$2**	3½'' O.D. plug	**$1.50**
1¼'', 1⅜''	**3/$2**	7½''	**$10**
1½''	**2/$2**	9½'', 10.4''*	**$15**
2''	**2/$2**	12½'', 12⅞''*	**$20**
2⅛''	**2/$20**	15.0'', 15.6'', 16''*	**$28**
5½''	**$6**	19'' (DS-16)	**$35**
*Fits Odyssey		21'' (Odyssey-II)	**$35**

Meade & Celestron
LUMICON carries a full line of telescopes and accessories. Fast Delivery, Competitive Prices.

LUMICON FOR HIGH PERFORMANCE

Visit our LUMICON web-site: http://Astronomy-Mall.com/Lumicon

NEW LUMICON MULTIPLE FILTER SELECTOR

$129

ALWAYS GET THE BEST VIEW!

$99
(If ordered with LUMICON filter or filter set)

The New LUMICON Multiple Filter Selector holds up to 5 1¼'' LUMICON filters. The sliding bar has a click-stop at each filter position. Now you can instantly select the best filter for any deep-sky object. Cost is $129 or $185 with 1.5X relay lens (for Newtonians). **Save $30 if ordered with filter(s)!**

TELE VUE™

NEW! Bino Vue Binocular Viewer

5X! Powermate boosts magnification 5X	**$179**
Ranger 70mm f/6.8 apochromat w/45° diag.	**$659**
Pronto 70mm f/6.8 w/45° erecting prism	**$889**
NEW! Bino Vue binocular viewer	**$899**
Gibraltar mount with ash wood tripod	**$535**
8, 11, 15mm Plossl . **$95**, 20, 25mm	**$105**
32mm Plossl, widest true field in 1¼''	**$125**
55mm 2'' Plossl, widest possible field	**$235**
2.0x or 3.0x Tele Vue Barlow Lens	**$119**
2'' Giant Barlow - 2x	**$185**
4.8mm Nagler, 82° field, 1¼'' eyepiece	**$175**
7mm Nagler, 1¼'' eyepiece, 82° field	**$225**
9mm Nagler, 82° field, 1¼'' or 2''	**$245**
13mm Nagler, 82° field, 1¼'' or 2''	**$315**
12mm Nagler, Type II, 82°, 1¼''/2''	**$295**
16mm Nagler, Type II, 82°, 1¼''/2''	**$315**
20mm Nagler, Type II, 82°, 2'' only	**$395**
2'' Paracorr Visual Coma Corrector	**$259**
15mm Panoptic 1¼'', 68° field	**$215**
19mm Panoptic 1¼'', 68° field	**$245**
22mm Panoptic 1¼''/2'', 68°	**$285**
27mm Panoptic 2'', 68° field	**$335**
35mm Panoptic 2'', 68° field	**$365**

TeleVue Warranty may not be valid outside USA.

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3'' & 2.1'' enhanced aluminum diagonal mirrors & 1¼'' star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32''	**$39.50**	1.52''	**$45.00**	1.83''	**$49.50**
2.14''	**$59.50**	2.60''	**$75.00**	3.10''	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼'' (1.32'' mirror)	**$99.50**
2'' (1.83'' mirror)(see photo above)	**$189.50**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." ***ASTRONOMY*, February 1991**

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

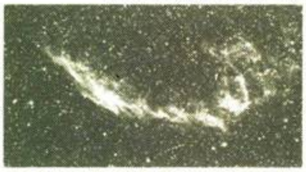
"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

BETTER THAN A DARK-SKY SITE!?

"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

	Premium*
1¼'' **LUMICON DEEP-SKY Filter** threads into most 1¼'' eyepieces	**$99.50**
48mm LUMICON DEEP-SKY Filter (1.7'' aperture), threads into most 2'' eyepieces. Also fits LUMICON EASY-GUIDERS	**$199.50**
2'' LUMICON DEEP-SKY Filter (1.5'' aperture), threads into most 2'' eyepieces. Also has male & female camera T-threads for prime focus photography	**$199.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	**$399.50**
2'' Rear Cell Filter, fits SCT's Deep-Sky, **$199.50** UHC, O-III, H-Beta,	**$199.50**
1¼'' LUMICON UHC Filter threads into most 1¼'' eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75'' aperture) fits most 2'' eyepieces	**$199.50**
Choice of ***any two*** LUMICON filters (**Save 7%**) 1¼'' **$185.00**; 48mm	**$370.00**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼''** **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼'' $99.50; 48mm**	**$199.50**
LUMICON Comet (Swan band) Filter **1¼'' $99.50; 48mm**	**$199.50**
Telephoto lens adapter for 2'' or 48mm filter. Select 46, 49, 52, 55, 58mm	**$7.95**
Universal adapter for 1¼'' filters. Adapts the 1¼'' filters to any 1¼'' eyepiece	**$19.50**
Universal adapter for 48mm or 2'' filters. Allows use of any 1¼'' eyepiece	**$25.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16'' aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6'', 8'', 10'', 11'', 14'', 16''

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) Filter.

Specify Lens Size	**H-Alpha**	**(DS)**
46, 48, 49mm	**$59.00**	**$199.50**
52, 55, 58, 62mm	**$69.00**	**$199.50**
67, 72, 77mm	**$79.00**	**$399.50.**
82mm (77mm + adapter)	**$89.00**	**$415.00**

Hypered 2415 film, 36 exp . . **$11.95, $3/$32**

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DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5'' plates and film up to 5X7''. Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2'' or 1¼''.

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$119.50**
Guider for Hasselblad **$489,** Mamiya 645	**$259**
Pentax 6X7 **add $129;** Pentax 645	**add $149**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER	**$249.00**
Adapter for Hasselblad **$299,** Mamiya 645	**$98**
Pentax 6X7 **add $129;** Pentax 645	**add $149**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12'' Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $179.50**
Adapter for Hasselblad **$399,** Mamiya 645	**$149**
Pentax 6X7 **add $139;** Pentax 645	**add $159**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** .... **$119.50** Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.
2. **Cable release** for long exposures . **$9.95**
3. **Declination motor** (state telescope type) **$109**
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.
5. **LUMICON EASY-GUIDER** (selection to left) .
6. **LUMICON 48mm DEEP-SKY FILTER $199.50** This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

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Film Type, 35mm	**Exposures**	**Price**
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Fuji G800 fine grain color neg.	**24**	**$13.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$8.50**

STAR STUFF

A PRODUCTS

Moonshot The Game

▶ An exciting new board game brought to you by the Galactic Attic, *Moonshot The Game* is designed to chronicle the epic adventure of America's race to the moon. The playing cards, designed with the collector in mind, provide endless game possibilities as well as historical information about the people, events, and machines that took us to the moon. The cards prompt players through the six phases of a lunar mission, modeled on Projects Mercury, Gemini, and Apollo.

The object of the game is to be the first player to complete any combination of six missions and land on the moon. To complete a mission, a player must use his or her fuel supply to launch the mission's required equipment and move a playing piece to the mission's corresponding patch on the game board. Once a mission has been completed, the player collects the mission patch and gains more fuel. The more fuel you have, the faster you can complete your missions, and special cards such as alarms and events add unexpected twists to the adventure.

MOONSHOT
MOONSHOT
MOONSHOT

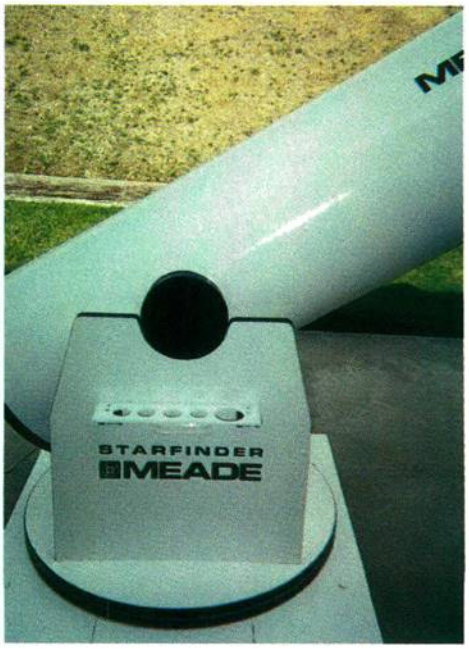
The first in a new series of historically accurate board games, *Moonshot The Game* is designed to be entertaining, easy to play, and educational. Special features include an individually signed and numbered Limited First Edition of 5,000 games, 180-card collector deck packed with digitally enhanced NASA photography, and 28 die-cut NASA mission patches. Intended for one to four players, ages 10 to adult, the game's average playing time is 30 to 60 minutes.

Galactic Attic, 1102 Dartmouth Street, Chattanooga, TN 37405; phone and fax, (423) 756-2237; website, http://www.galacticattic.com. *Moonshot The Game*: $39.95.

Dob-Eye Eyepiece Holder

▶ Have you ever accidentally knocked extra eyepieces off of your telescope base while viewing? The *Dob-Eye Eyepiece Holder* makes this a problem of the past. It also eliminates the constant stooping and bending necessary for changing eyepieces — it puts them at arm's length to make observing a pleasure, not a workout. The *Dob-Eye* fits most Meade, Orion, Celestron, Odyssey, and homemade Dobsonian telescopes. Quick and easy to install, the *Dob-Eye* slides easily in and out of supplied brackets once you have mounted them to your telescope, allowing for easy transport of your telescope from car to field.

Krygier, 840 Chestnut Street, Ontario, CA 91762; phone, (909) 986-5706, ask for Kevin. *Dob-Eye Eyepiece Holder*: $20.



Earth Science/Space Science Study Kits

▶ Hoping to make science a more hands-on, interesting, and informative subject for students, Sarah Kennedy, educator, scientist, and publisher, has developed a series of products to help educators more easily teach in-depth information in the classroom. The study kits are geared toward middle and high schools, special programs, and gifted and talented programs.

Meteorite Study Kit, the first in the series, contains an invaluable teacher's guide written by Paul Hodge of the University of Washington, an authority on world impacts. Chapters cover topics such as primitive meteorites, impact sites and products, asteroids, and near-Earth objects. The kit also includes six color, laminated World Impact Maps, researched and developed by Kennedy and Hodge, as well as study samples, suggestions and instructions for experiments, a magnet, and a magnifier.

METEORITE STUDY KIT

Other kits from this series include *Elements of the Universe*, helping to teach astronomy, mineralogy, and chemistry, and the *Moon Rocks/Earth Rocks Mineral Study Kit*, containing rock samples, soil samples, and vial samples of Earth materials with the same types of minerals and soils as those brought back from the moon by the Apollo missions. With the aid of these kits, the job of teaching science to children will seem easy.

Jensan Educational Products, 6183 Woodland Drive, Grand Blanc, MI 48439; phone and fax, (810) 694-3802; toll-free, (800) 720-5451; website, http://www.jumpoint.com/jensaned. *Meteorite Study Kit*: $85; *Elements of the Universe*: $260; *Moon Rocks/Earth Rocks Mineral Study Kit*: $135.

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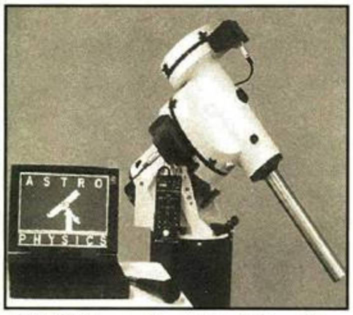

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STAR STUFF

Visual Star Spectroscope

▶ Amateur astronomers now have the ability to discover the differences between the spectra of hot-, cool-, and medium-temperature stars using the *visual star spectroscope* recently released by Rainbow Optics. The spectroscope will attach easily to the top of 1.25- and 0.96-inch eyepieces with eye-end diameters of 1.5 inches or less (measurements that are typical of most Plössls, Kellners, and orthoscopics).

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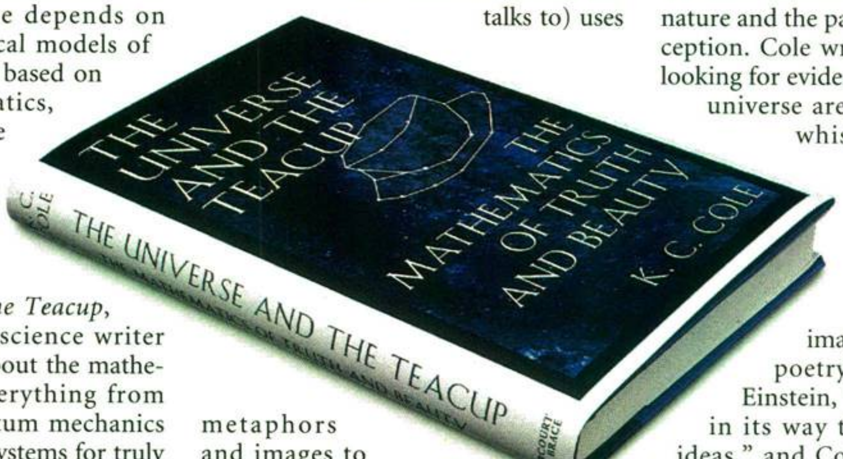
Rainbow Optics, 1593 "E" Street, Hayward, CA 94541; phone, (510) 581-8266. *Visual star spectroscope*: $149; *Visual/photo/CCD star spectroscope*: $199.

A BOOKS

The Universe and the Teacup: The Mathematics of Truth and Beauty

K. C. Cole, 214 pages, Harcourt Brace, New York, 1998; ISBN 0-15-100323-8; hardcover, $22.

▶ Thousands of years ago our ancestors looked into the night sky and saw, twinkling above them, the heroes and gods of their legends. Now, in the wake of Copernicus, Newton, and Einstein we scan the skies for distant galaxies, pulsars, and black holes. How we interpret what we see depends on sophisticated theoretical models of the universe which are based on complicated mathematics, not myths; but we are still standing on the edge of everything trying our best to tell stories that make sense of it all.


THE UNIVERSE AND THE TEACUP
THE MATHEMATICS OF TRUTH AND BEAUTY
K. C. COLE
K. C. COLE
THE UNIVERSE AND THE TEACUP
THE MATHEMATICS OF TRUTH AND BEAUTY
HARCOURT BRACE

The Universe and the Teacup, by *Los Angeles Times* science writer K. C. Cole, is a book about the mathematics underlying everything from astrophysics and quantum mechanics to the development of systems for truly fair democracy and divorce settlements. It's not a book about numbers, though; it's about the words and images we use and the stories we tell to help ourselves understand the numbers that make the universe work. Cole combines insights from numerous interviews with mathematicians and scientists together with her own clear, concise explanations, demonstrations, and analogies and is able to bring subatomic particles and intergalactic space into focus at a scale we can understand.

First, Cole discusses the way our minds deal with math. "Number numbness" (the result of our brains' weak "exponential sense") makes it hard to do things like recognize the vast difference between a billion and a trillion (if a trillion is 10 meters, a billion is only one centimeter). Number numbness is part of the reason it's so difficult to understand inflation, the national debt, and the universe's size.

To overcome these fundamental weaknesses in the hardwiring of our brains, Cole (along with the scientists and mathematicians she talks to) uses metaphors and images to explain, in ways that our brains can understand, topics like chaos, game theory, and the underlying symmetry that drives both the creation of snowflakes and the theory of relativity. Cole tries to tie all of these things together, comparing, for example, the physical and social sciences. Often she succeeds in making things clearer, but sometimes her comparisons seem disjointed.

Cole's anecdotes reveal what math does and what it can't do (because of the complex array of calculations and interrelated forces involved, a mathematician will never be able to predict as well as an outfielder the flight of a batted baseball). She also shows how math (along with physics, chemistry, and astronomy) works: by shifting frames of reference and using logic and methodology to sift through mountains of data to find what matters most.

"Facts rarely present themselves cleaned up and alone, ready to be admired and fussed over," Cole writes. Before we can make sense of the world, we have to unravel the patterns in nature and the patterns in our own perception. Cole writes that astronomers looking for evidence of the origin of the universe are "trying to pick up a whisper in the roar of a crowd," or searching for a "dust mote . . . on a skating rink," as one astronomer puts it.

These sublime images have the power of poetry. Cole quotes Albert Einstein, "Pure mathematics is in its way the poetry of logical ideas," and Cole herself writes that math is both "a language and a literature." *The Universe and the Teacup* is both a kind of lexicon and an anthology of the literature of math. Unfortunately, Cole covers so many topics that she isn't able to explore them in depth; she never takes readers through the process of actually doing real math. She makes tantalizing references to things like a bizarre quantum particle called a "spinning nothing" and Richard Feynman's notion that antimatter particles are "moving backward in time" but

Earth

IN THE JUNE ISSUE

THROUGH THE EYES OF A DINOSAUR

With modern lasers, ancient skulls, and model eyes, one researcher has learned what dinosaurs really saw — and whether they were predators or scavengers.

WHEN EARTH FELL SIDEWAYS

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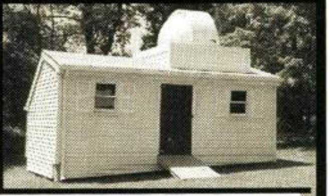

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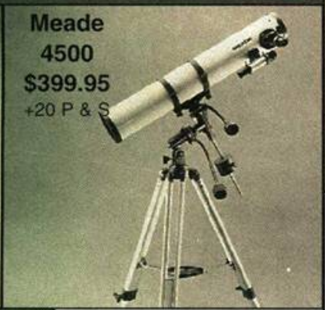

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offers no explanation of what they mean. Also, in a book on the mathematics of truth and beauty, Cole glosses over or omits a few key concepts, like a discussion of how numbers — the golden mean, classical proportions, and the Fibonacci sequence — relate to the shapes our eyes have come to adore in nature and in art.

These minor criticisms aside, Cole helps to teach us that math is more than just a tool to balance our checkbooks. It's the key to understanding the beauty of a rainbow and to discovering our true place in the universe. "It took an enormous amount of imagination to see that from the sun's point of view we move in circles around it," Cole writes. Mathematical thinking has raced beyond the Copernican solar system into the heart of time, matter, and energy. The scientists and mathematicians who have organized the universe into the periodic table of elements, categories of wavelets, and families of subatomic particles that Cole introduces here have created a whole new sky full of constellations for us to gaze at in wonder and struggle to understand by spinning beautiful stories in the language of math. — *Jake Miller*

Other Books

Splendors of the Universe — A Practical Guide to Photographing the Night Sky

Terence Dickinson and Jack Newton, 144 pages, Firefly Books, Buffalo, New York, 1997; ISBN 1-55209-141-4; hardcover, $40.

▶ Two renowned astrophotographers have teamed up and the result is *Splendors of the Universe,* a book that combines a beautiful showcase of images captured by amateur astronomers using cameras and telescopes with practical information that is intended to guide readers clearly and easily in their own astrophotography attempts.

The astrophotography of authors Terence Dickinson and Jack Newton has regularly graced the pages of *Astronomy,* and their photos, as well as those of several other amateur astrophotographers, make this book brilliantly beautiful. In addition, Dickinson and Newton have provided readers with lucid and concise text, which they have chosen to write in first person in order to more naturally convey their own personal experiences and comments.

In an attempt to "cover it all," Dickinson and Newton have included everything from very basic camera-on-tripod constellation shooting to the more complicated though increasingly popular use of state-of-the-art telescopes and CCD cameras. Their hope is to provide information that is valuable to a vast audience, one that spans a wide range both in terms of experience in the astrophotography field and in terms of the quality and caliber of equipment used.

Filling what they have determined to be a void in works previously published on astrophotography, the authors of *Splendors of the Universe* have chosen to concentrate on guiding readers toward more creative astrophotography. They have selected many photographs that they feel "realize the maximum possible splendor in the astronomical shot," hoping through example to help teach amateurs to take professional looking pictures. And because they've chosen to showcase only the most captivating shots of the universe, the book is every bit as beautiful as it is informative.

— *Jeanette Brown*

The Once and Future Moon

Paul D. Spudis, 308 pages, Smithsonian Institution Press, Washington, DC, 1998; ISBN 1-56098-847-9; softcover, $17.95.

▶ Beginning with an informative account of the history of lunar exploration, *The Once and Future Moon* goes on to outline what has been learned thus far about the moon's composition, to chronicle the observation and exploration performed by the Apollo missions, and to speculate about what the future may hold in terms of establishing lunar colonies. Spudis, a geologist at the Lunar and Planetary Institute in Houston, has spent a great part of his career studying the feasibility

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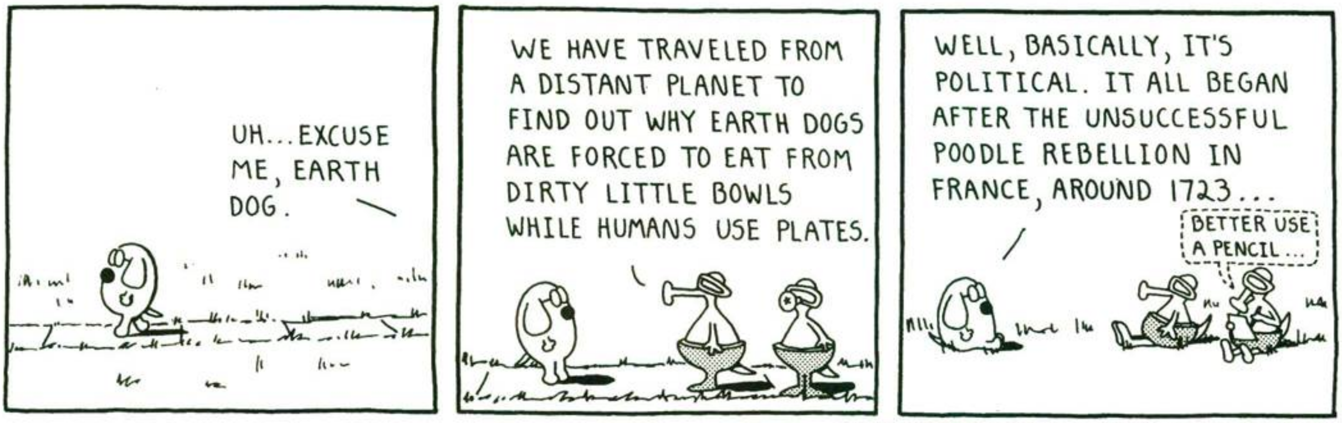
Eclipse Zone:
http://www.geocities.com/CapeCanaveral/7137/ez.htm

Fred Espenak's 1998 Solar Eclipse Page:
http://planets.gsfc.nasa.gov/eclipse/TSE98reports/TSE98Espenak.html

Exploratorium Expedition in the Caribbean
http://www.exploratorium.edu/eclipse/

Bob Yen's Solar Eclipse Site:
http://www.comet-track.com/eclipse/secl.html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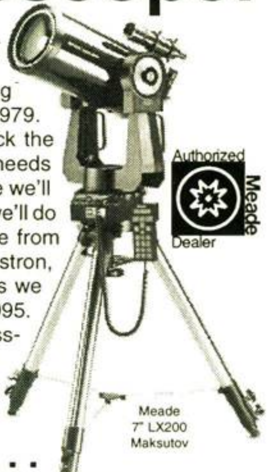
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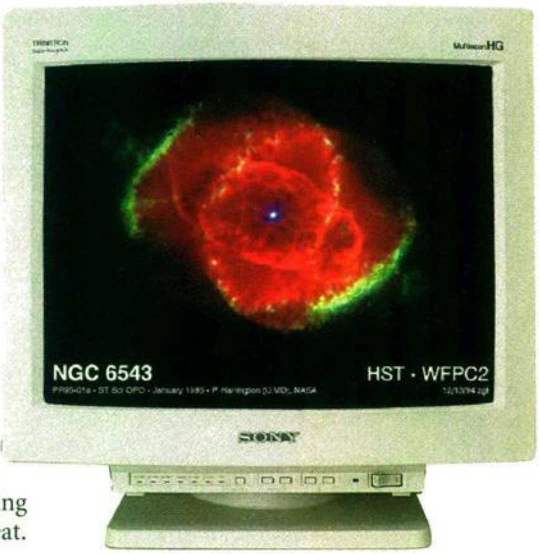

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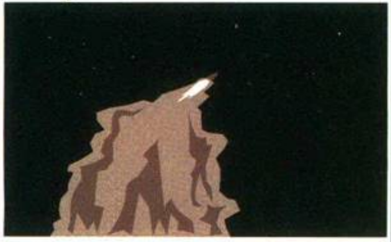
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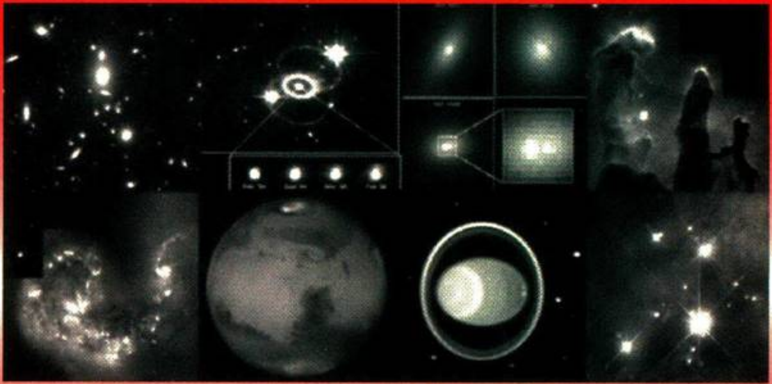
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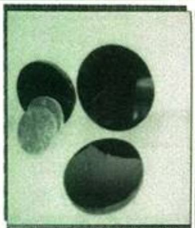

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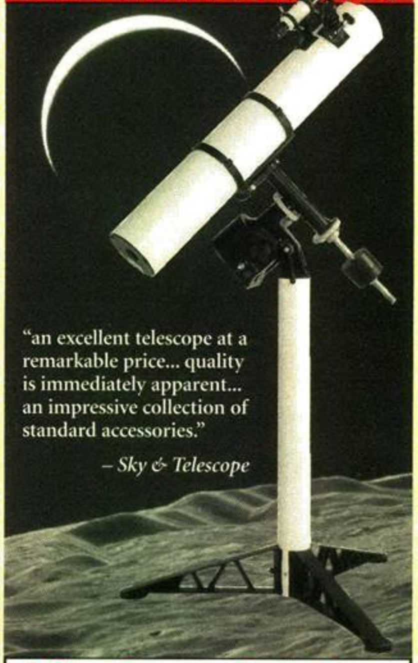

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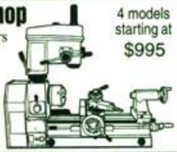

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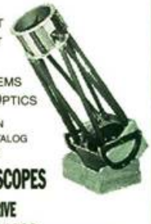

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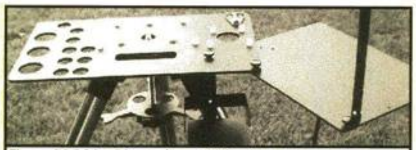

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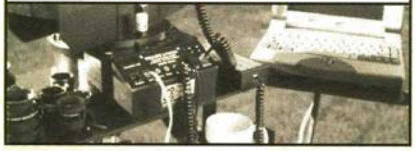

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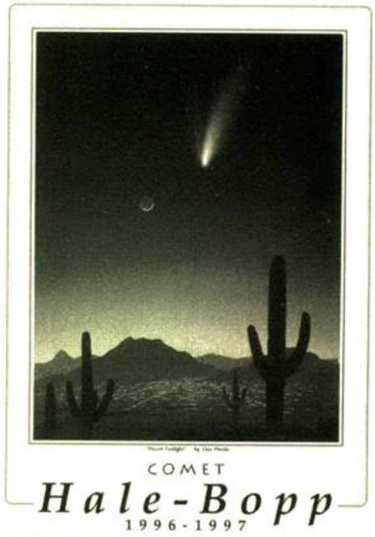

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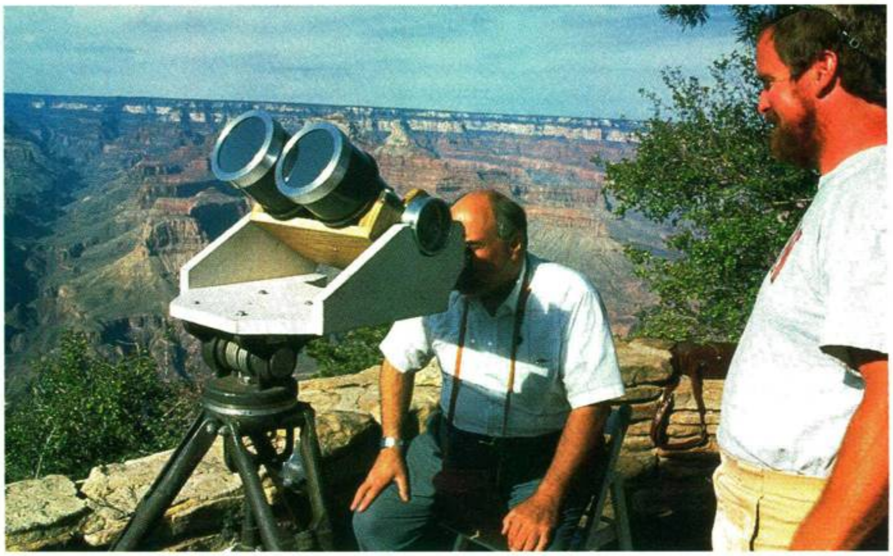
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Dean Ketelsen (right) shares his 25x120 binoculars at the Grand Canyon Star Party.

JUNE 7–11

Annual Meeting of the American Astronomical Society

▶ Town and Country Hotel and Convention Center, San Diego, California. Contact Millie Durbin at AAS Meeting Registration, American Astronomical Society, 2000 Florida Ave., N. W., Suite 400, Washington, DC 20009; (202) 328-2010; fax, (202) 234-7850; e-mail, reg-help@aas.org.

JUNE 12–13

Apollo Rendezvous and Telescope Fair

▶ Dayton Museum of Discovery, Dayton, Ohio. For more information, write to the museum at 2600 DeWeese Parkway, Dayton, OH 45414; or e-mail Terry Mann at starsrus@infinet.com.

JUNE 13–20

Grand Canyon Star Party

▶ North and South Rims of the Grand Canyon National Park, Arizona. Sponsored by the San Francisco Sidewalk Astronomers, the Tucson Amateur Astronomy Association, and the National Park Service. Contact Dean Ketelsen, 1122 East Greenlee Place, Tucson, AZ 85719; (520) 293-2855; e-mail, ketelsen@as.arizona.edu.

JUNE 19–20

Craters of the Moon Star Party

▶ Craters of the Moon National Monument, north of Salt Lake City, Utah. Contact Jay Sneddon, (208) 736-2447; e-mail, jsneddon@aspenepeo.com; website, http://www.geocities.com/CapeCanaveral/Launchpad/2675/.

JUNE 19–20

Greater Verde Valley Astronomy Festival

▶ Red Rock State Park, Sedona, Arizona. Sponsored by the Idaho Falls and Magic Valley Astronomical Societies. Contact Russell Nidey, (520) 634-7332, e-mail, rnidey@verdepo.yavapai.cc.az.us.

JUNE 19–21

Jersey Starquest

▶ Hope Conference and Renewal Center, Hope, New Jersey. Sponsored by the Amateur Astronomers Association of Princeton. Contact William Murray, P.O. Box 2017, Princeton, NJ 08543.

JUNE 19–21

Mason Dixon Star Party

▶ Spring Valley County Park, near York, Pennsylvania. Sponsored by the York County Astronomical Society. Contact Jeri Jones, 400 Mundis Race Road, York, PA 17402; (717) 840-7226; e-mail, JLJ276@aol.com; website, http://home1.gte.net/dmdewey/mdsp.htm.

JUNE 19–21

Spring Meeting of the American Association of Variable Star Observers

▶ University of Colorado at Boulder. Contact AAVSO – Meetings, 25 Birch Street, Cambridge, MA 02138; e-mail, meetings@aavso.org.

JUNE 19–21

Wisconsin Observers Weekend

▶ Hartman Creek State Park, near Waupaca, Wisconsin. Contact Terry Becker, 514 Union Avenue, Apt. E, Oshkosh, WI 54901; (920) 426-2286; e-mail, tlb@vbe.com.

JUNE 25

Astronomy's 25th Anniversary Star Party

▶ Rio Rancho Balloon Fiesta Park, Rio Rancho, New Mexico. Afternoon to midnight. For more information, write to *Astronomy*'s 25th Anniversary Star Party, c/o *Astronomy*, P.O. Box 1612, Waukesha, WI 53187-1612; website, http://www.astronomy.com.

JUNE 26–27

Summer Solstice Star Party

▶ Northern Cross Observatory, Hartland, Michigan. Contact Doug Bock, (810) 750-0273; website, http://kode.net/~dougbock.

JUNE 26–28

Rocky Mountain Star Stare

▶ Pike National Forest, Colorado. For more information send a SASE to RMSS '98, Colorado Springs Astronomical Society, P. O. Box 62022, Colorado Springs, CO 80962; e-mail, bygrens@aol.com.

JUNE 27–28

Universe '98

▶ Hyatt Regency Albuquerque, New Mexico. Sponsored by *Astronomy* magazine and the Astronomical Society of the Pacific. Contact Laurie Keechler, ASP, 390 Ashton Avenue, San Francisco, CA 94112; (415) 337-1100; e-mail, lkeechler@aspsky.org; website, http://aspsky.org/u98/u98.html.

CONTACT

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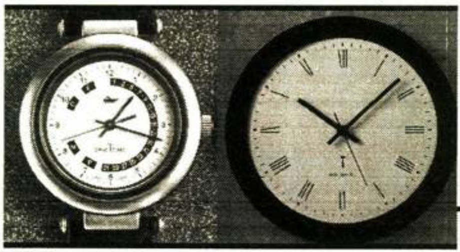

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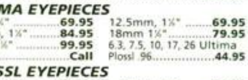

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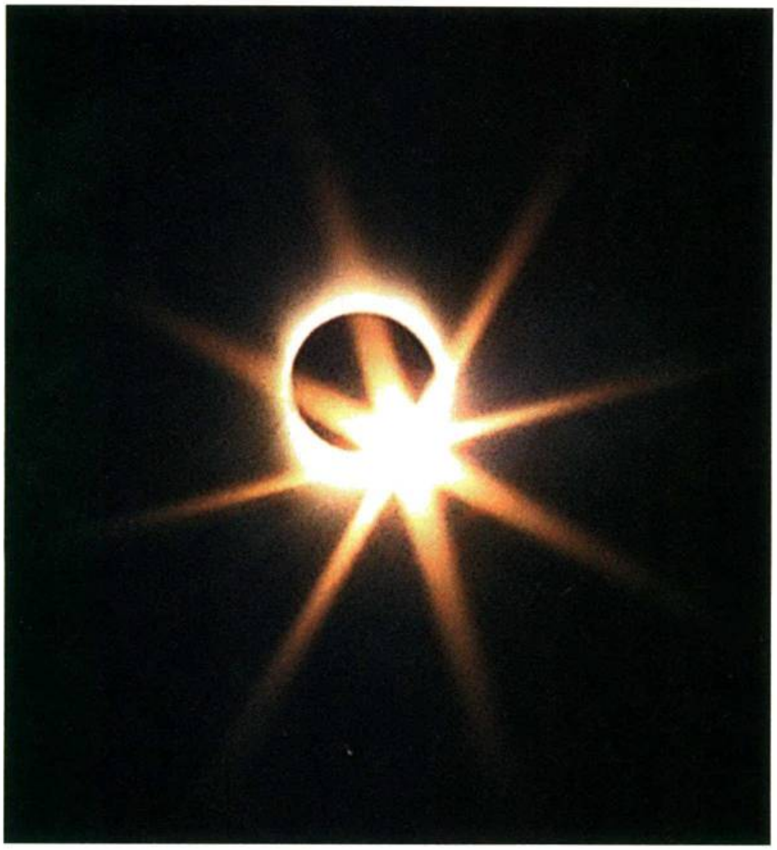
SHADOW SURFING

Wish You'd Been There

▶ My first solar eclipse was the most beautiful sight. As a photographer, I was struck most by the light, or rather darkness, that made color so rich that it seemed to lend texture to everything I saw. Enveloped in the moon's shadow as it moved across the ocean, I looked up as the planets slowly winked on — Venus, Jupiter, then Mercury. When we reached the point of nearly complete darkness, we were left with an incredible scene over our heads of the sun hidden behind the moon, bathing us only in the corona. Everybody let out a yell as hands clapped and mouths dropped. It was a priceless experience that I'll share forever with the friends who were with me that day. — *Raleigh Souther, Photo Editor,* Los Angeles Times, *Los Angeles, California*

After being clouded out of three previous eclipses, this was simply the loveliest and most impressive act of nature I have ever experienced. It was wonderful to share with a friend and stunning enough to want to witness again. — *Michael Oblath, El Cerrito, California*

My husband and I observed the February 26, 1998, total solar eclipse from the *Galaxy* cruise ship in the Caribbean. This was our second total solar eclipse and as with our first, on July 11, 1991, the occurrence was startling, beautiful, and unforgettable. — *Camille Chidester and Joe Green, Simi Valley, California*



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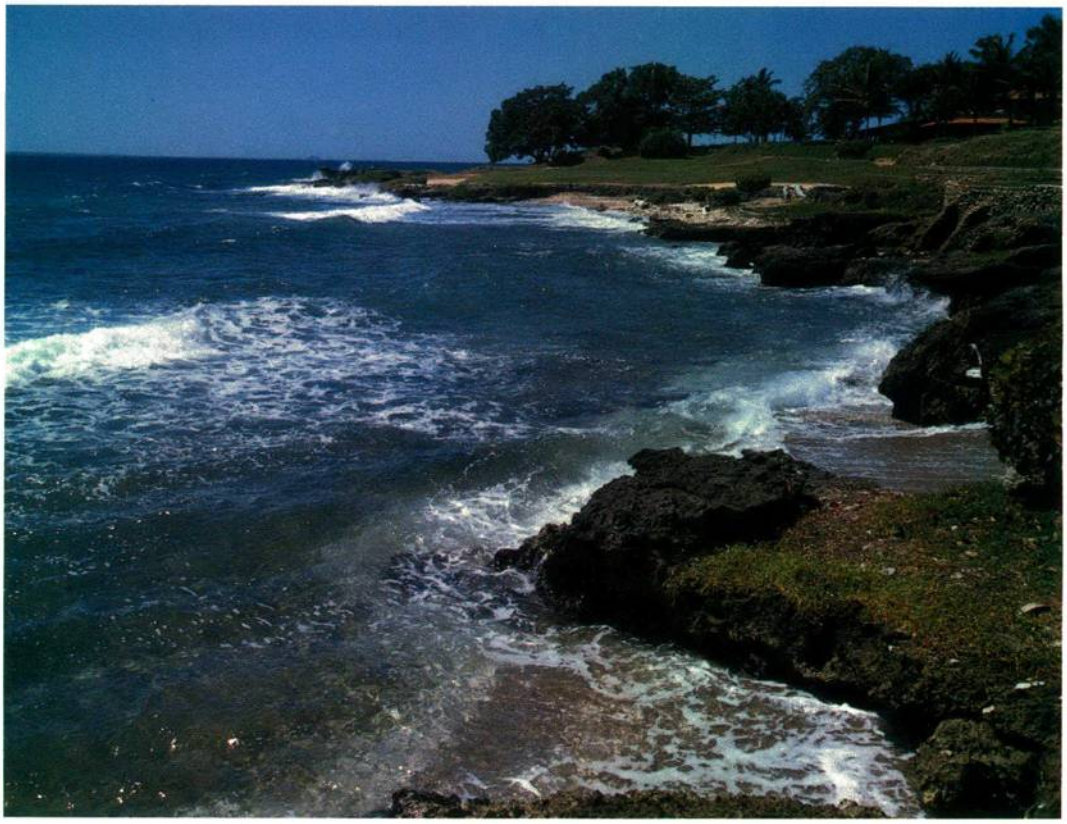
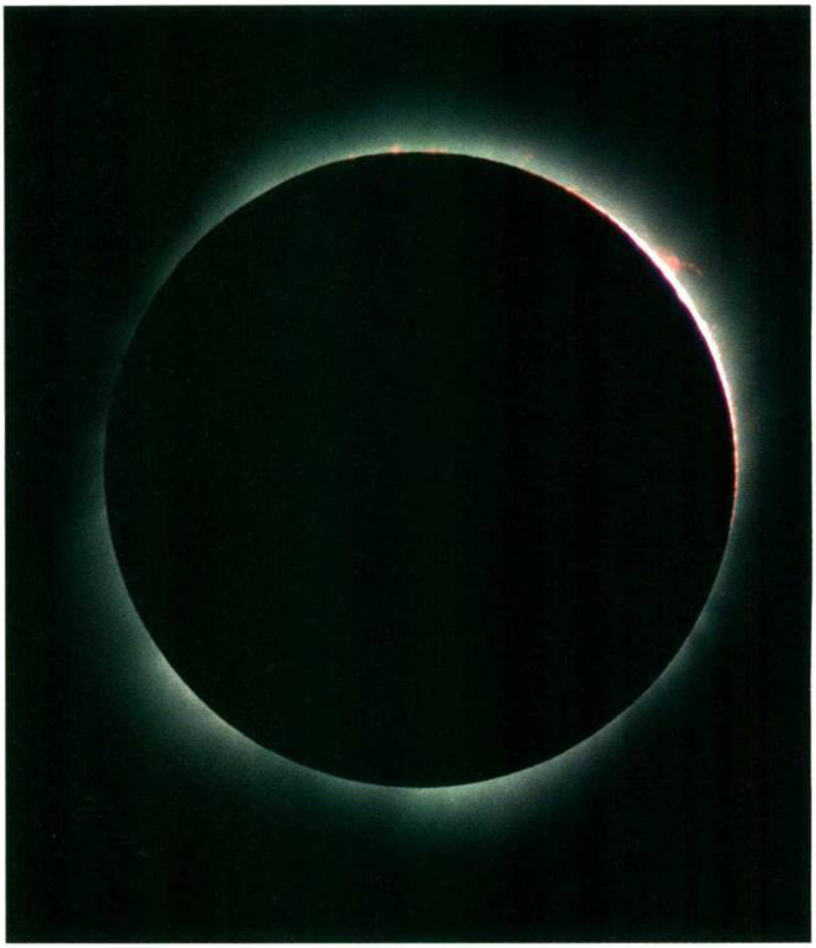


It's amazing that such a geometrically simple event can be so gorgeous. It was an extraordinary moment atop the *Galaxy*: Above me was a total solar eclipse, to my right was an actively erupting volcano (on the island of Montserrat), and on board the boat was bar service. Life rarely gets much better than that. — *Ron Wharton, New York, New York*

Was that an eclipse or what? What a magnificent corona. Beautiful streamer structures, outstanding coronal brushes, and brilliant red prominences. I can still close my eyes and see it as if I were looking at it right now. Both the ingress and egress diamond rings seemed to last forever. I could see corona at least 15 seconds before and after second and third contact, much longer than the July 1991 eclipse. I observed the eclipse from in front of the Aruba Radisson. Ed Faits, one of the guys in my group, used his Astroscan to project the partially eclipsed sun onto a screen for all to view while the rest of us clicked photos through our scopes. All in all, this was a terrific trip and a wonderful eclipse. — *Phil Harrington, Smithtown, New York*

I think Mercury and Jupiter stole the show. I've never seen all five naked-eye planets during one eclipse before. Mercury, nearly as bright as Jupiter and 65° high in the sky, was tremendous. Watching from Venezuela, one woman came up to me after the eclipse in tears. She expressed her deep appreciation for being able to participate in "the single most beautiful natural phenomenon she'd ever seen." — *Dan Koehler, Waukesha, Wisconsin*



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Montserrat Volcano Belches After the Eclipse

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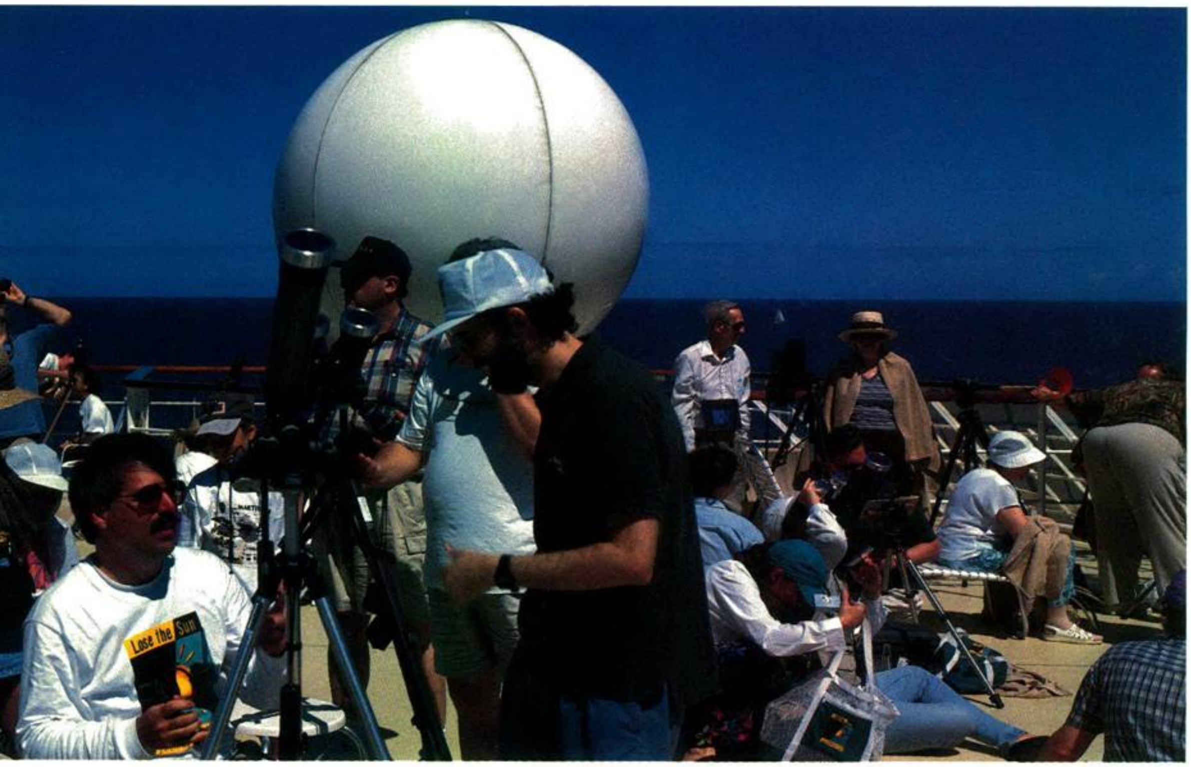
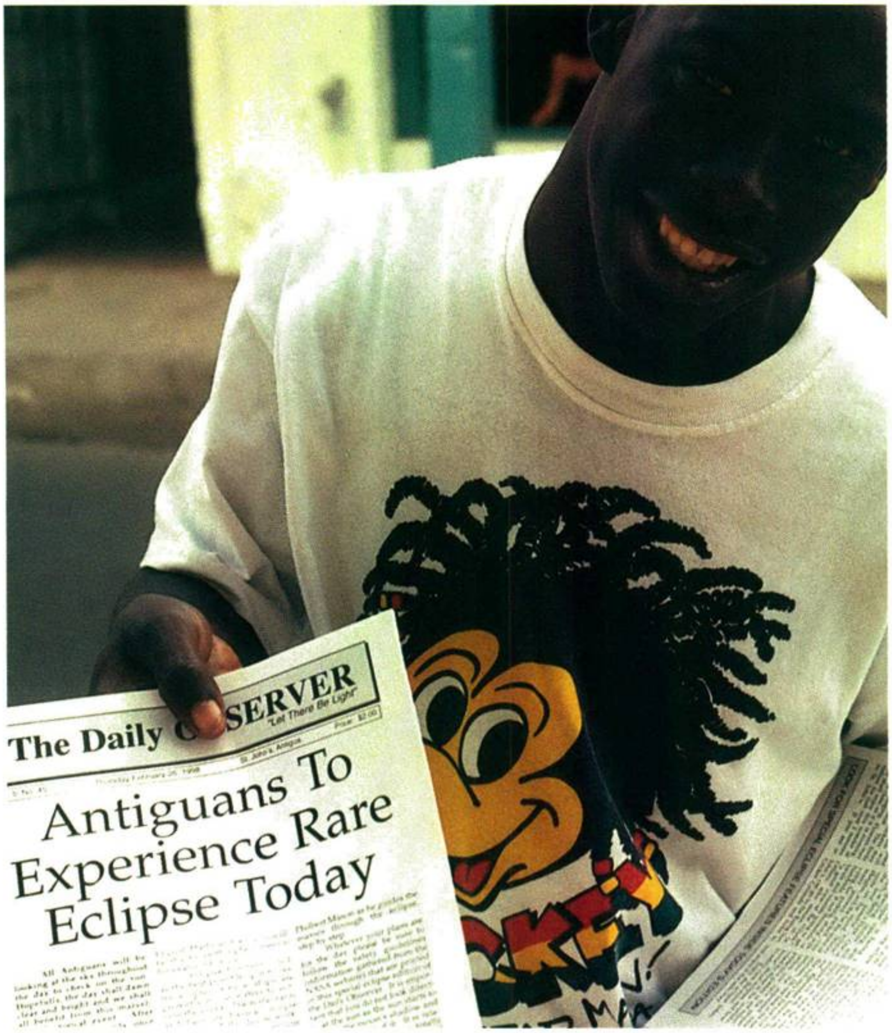


On Deck the Crowd Starts to Gather

RYAN ROULETTE

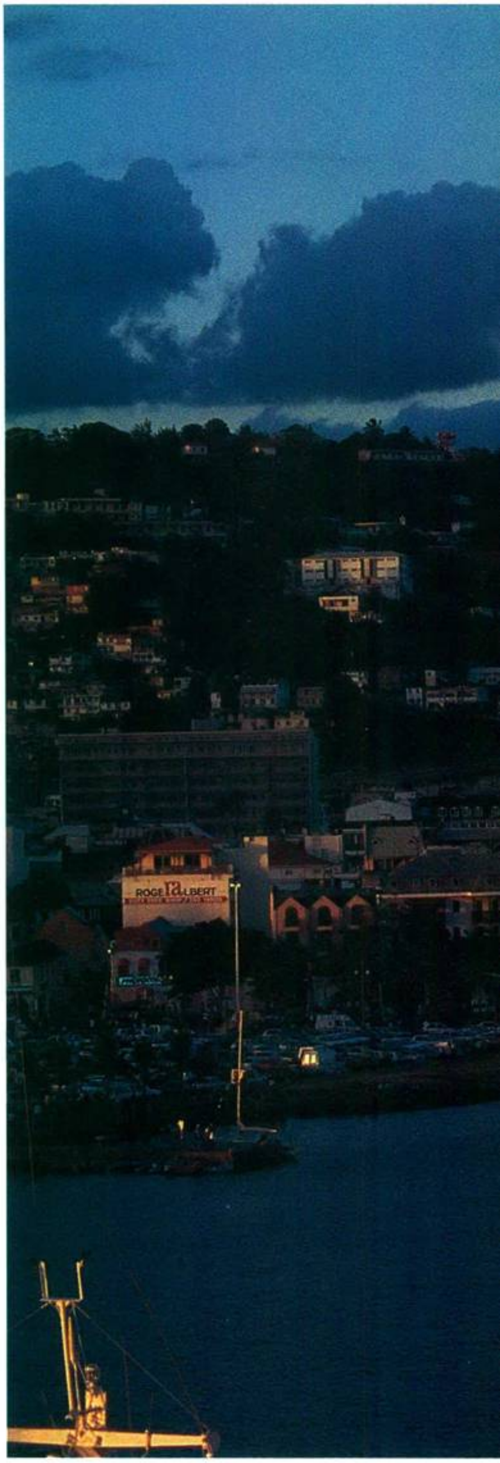
Antiguans Gear for the Eclipse

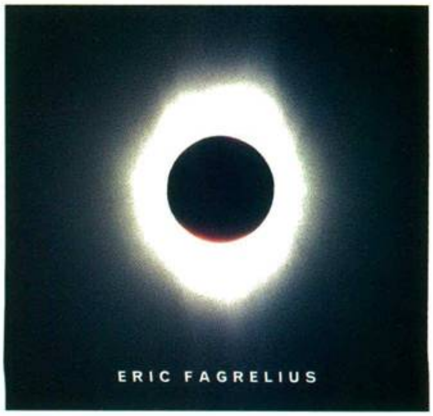
DENNIS AND JUDY STARK

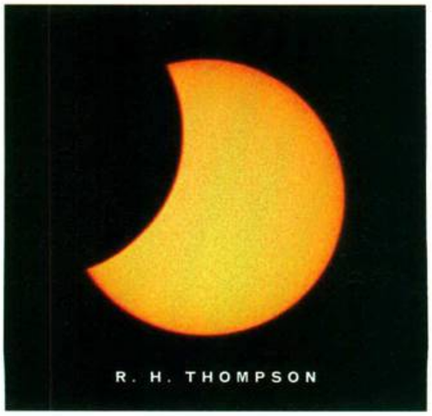

The Daily Observer
"Let There Be Light"
Antiguans To Experience Rare Eclipse Today

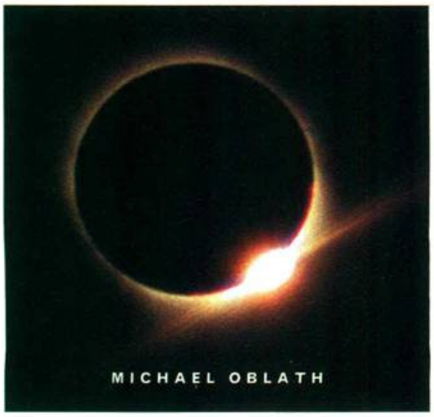
Sunset and Sails on Martinique

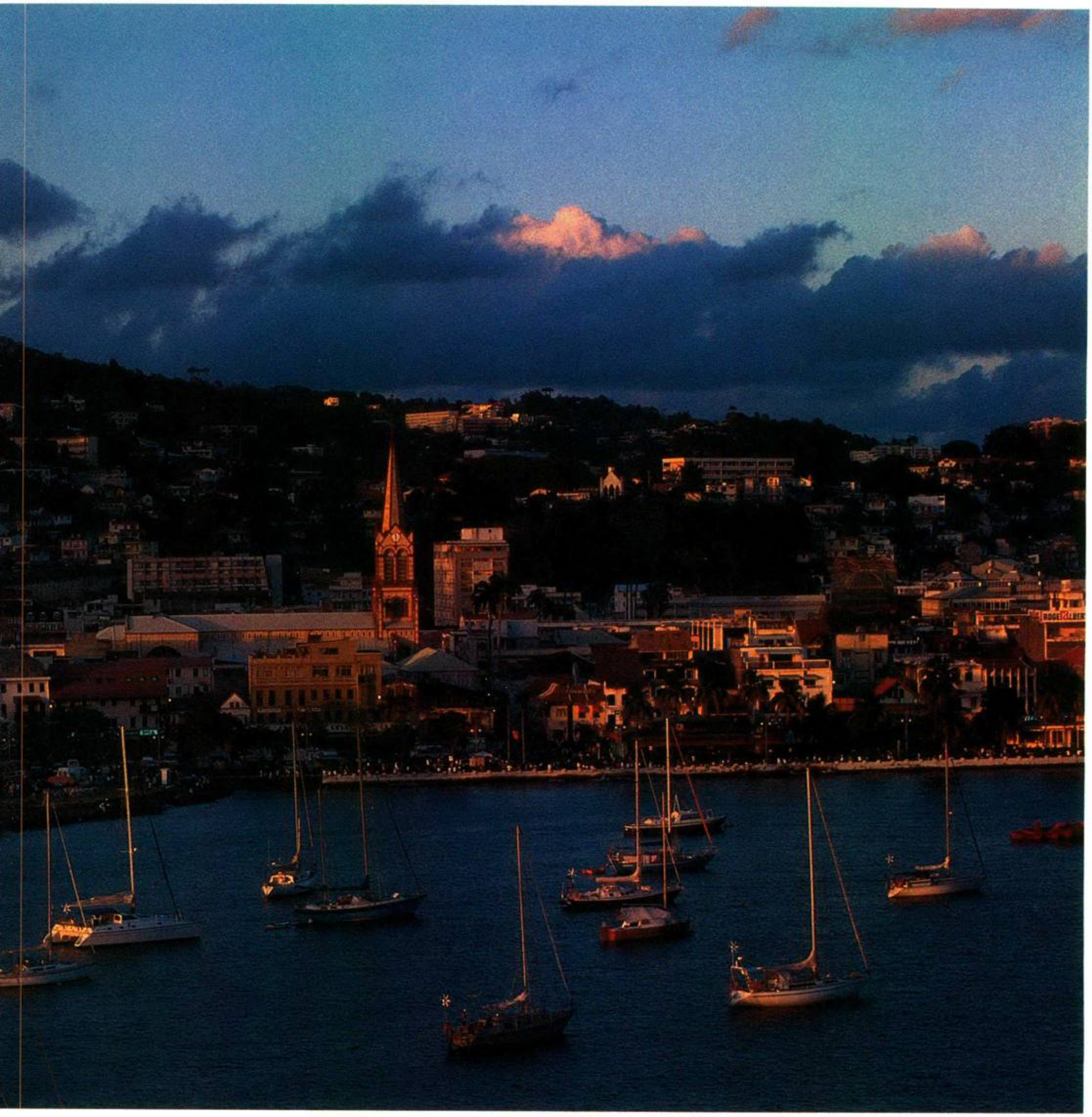
RYAN ROULETTE



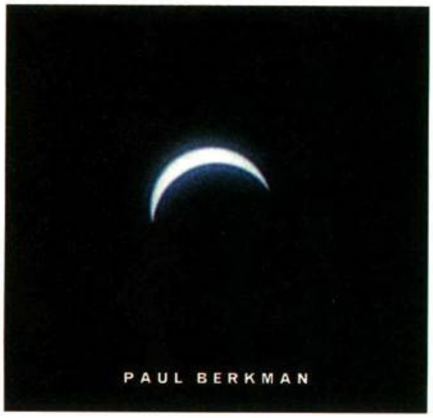

ERIC FAGRELIUS


R. H. THOMPSON

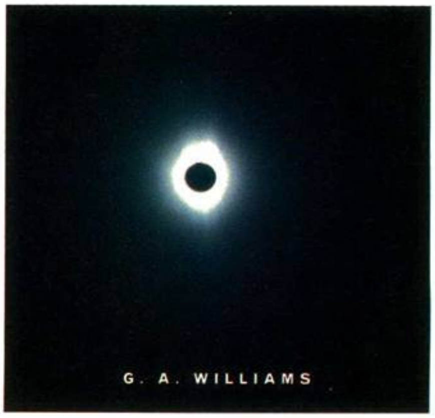

MICHAEL OBLATH



JOHN C. PEARSON



PAUL BERKMAN



G. A. WILLIAMS

To see our on-line photo of the week, visit our website at http://www.astronomy.com.

Sky and Planets at Totality

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Baby Bananas on Martinique

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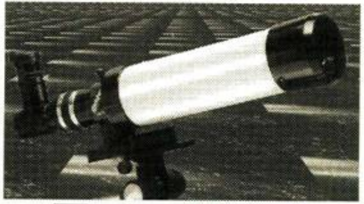

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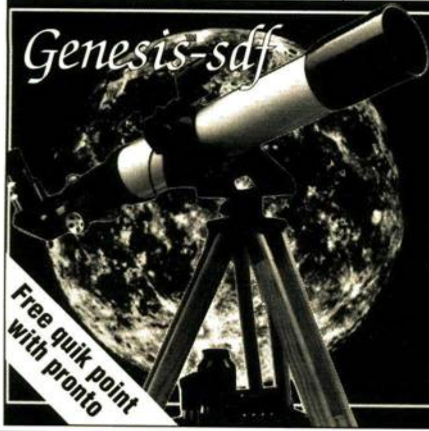

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Photo of Horsehead Nebula taken with Pronto by Ralph Sieger

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